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THROUGH THE EYES OF THE EDITOR

Ira E. Klein suggests that each dentist become skillful in the use of a basic impression procedure. The use of a more or less standardized procedure with materials of known working properties would provide a basis for comparison with other procedures and materials as they are suggested. The basic procedure selected should be one that meets all of the requirements for good impression making. He describes his basic procedure and the modifications which he makes in it to meet specific mouth conditions. The use of alternate materials and methods to accomplish specific results is a sound approach to the problem.

David Disick describes a technique for making an emergency temporary denture. While it is obvious that a denture made in this manner could not be satisfactory as a permanent restoration, it could save a patient from an embarrassing situation. The procedure is simple enough to be practical in an emergency and is another example of the versatility of modern plastics.

Jerome M. Schweitzer discusses the Transograph and the concept back of the instrument. This was a difficult assignment because of the obscure terminology which has been used previously in articles relating to this subject. An honest effort has been made to use terms that have meaning to contemporary dentists rather than to make the article *appear* erudite. Further progress could have been made in this direction.

There are many points in this article which are open to question. For example, it is stated that centric relation is a useless record because it represents "one static position." Any static record is a record of one position selected from all other positions. If all possible static positions are recorded, no error could exist, provided they are *all* recorded *correctly*. This would then encompass the entire envelope of motion. If centric relation is *not* recorded accurately, malocclusions could exist at this position even if all of the other positions were correctly recorded and reproduced on an instrument. This really means that the "centric relation" and the posterior terminal "hinge axis" registrations are identical *provided* they are made at the *same* vertical jaw separation. Whether or not the vertical dimension on the articulator can be increased or decreased from this "correct registration" will depend upon the accuracy of the orientation of the casts on the articulator. Centric relation involves one specific position of the mandible, and other registrations are necessary if all of the essential eccentric relations are to be reproduced correctly upon the articulator. Apparently Transographics does not recognize this fact. Instead, its concern is with the relations of teeth when *they are not in contact,* but when they are approaching contact. Obviously, teeth must not interfere with each other as they approach each other. It is unfortunate that authors writing on the theory of Transographics have attempted to tear down many of the previously recognized concepts. When the theory of Transographics is analyzed, section by section, much of it is only a rewording of other current concepts, and a distortion of these concepts, in some instances.

Vincent R. Trapozzano discusses the article "The Transograph and Transographic Articulation" by Jerome M. Schweitzer and

points out some of what he believes to be fallacies in the ideas expressed in this article. This discussion should provide a stimulus to further analysis of the concepts of Transographics.

Richard L. Myerson discusses the use of porcelain and plastic teeth opposing each other in dentures. Both clinical and laboratory tests were made, but more clinical evidence should be collected before sound conclusions can be drawn. The fact that plastic teeth do wear away is not disputed, and this wear is reduced markedly when the teeth of only one denture are of plastic, *provided* the porcelain teeth are glazed or highly polished. This seems to bear out the clinical observation that the loss of tooth substance from plastic teeth results from the abrasion of foods rather than from the contacts made by the opposing teeth. If food is the abrasive, and if it affects only the plastic teeth, the *total* wear would be reduced.

C. W. Sauser and A. A. Yurkstas report their tests of the chewing efficiency of various occlusal forms. The test occlusal forms were attached to natural posterior teeth in order to eliminate some of the variables that exist when tests are made on dentures. The necessary increase in the occlusal vertical dimension undoubtedly changed the chewing "habits" of the subjects, but it is likely that during the large number of tests, some accommodation was made by the subjects. It is unfortunate that comparisons were not made with cusp teeth at the same level of occlusion.

William H. Pruden II describes a unilateral free-end partial denture and the technique for its construction. He makes use of splinting, semiprecision attachments, and stress-breaking. The appliance seems to overcome some of the objections to unilateral removable restorations, but it seems that bilateral stabilization would improve it. Also, a larger appliance would be less likely to be swallowed by the patient.

B. F. Levene, Jr. discusses occlusion as it is related to various aspects of general practice. He points out the effects of malocclusion in various situations. There may be some question of the statement that the large errors are the most damaging. Clinical observation seems to indicate that the small, difficult to detect errors cause much trouble for complete denture wearers. When natural teeth are present, the proprioceptors of the periodontal membrane are sufficiently sensitive to control jaw movements. This is not true with complete dentures in most instances. His emphasis of the importance of tooth contacts on the balancing side is especially important when these contacts are made before the working side teeth contact. A premature balancing side contact is probably the most damaging occlusal disharmony, regardless of the type of dentition or restoration.

John C. Bartels discusses diagnosis and treatment planning with a proper emphasis upon consideration of the entire masticatory organ as a unit. He takes general systemic factors into consideration and relates them to the local problems in the mouth. The value of this approach to diagnosis and treatment planning cannot be ignored. Modern dental treatment consists of more than repairing the holes in teeth and filling the spaces where teeth are missing. While this plan may involve more than caring for the immediate needs of the patient, it will, in the long run, protect the patient from recurring and even more extensive dental disorders.

Arthur S. Freese reviews the anatomy of the temporomandibular joint and discusses the degenerative diseases of this joint. He attributes most of the symptoms of temporomandibular joint symptoms to degenerative disease and doubts the validity of Costen's analysis of the problem. He suggests that this joint can be treated in a manner similar to that for degenerative diseases in other joints in the body. This is an interesting approach which coincides with that of several other investigators who are working on this problem.

Vincent A. Pugnier suggests that heat applied to porcelain teeth during the fabrication of prosthetic appliances may aggravate inherent defects in the teeth and weaken them to the point where they may fracture. He used an "electrified-particle inspection method" to detect defects that were not visible to the naked eye. The amount of damage to a tooth is apparently proportionate to the amount of thermal shock.

Joseph R. Jarabak recognizes two main problems in prosthodontics as being the interocclusal distance and the vertical height of

the restorations. He used electromyography as the means for his study and makes his analysis on the basis of electromyographic recordings made from electrodes placed over selected muscles. His description of the neuromuscular system is simple, understandable, and adequate for his purpose. He studied groups of both dentulous and edentulous patients and compared the electrical activity of muscles of edentulous patients with varied interocclusal distances. These studies emphasize the importance of an adequate interocclusal distance when the mandible is in rest position, and the importance of the proprioceptors in the periodontal membrane to the establishment of the centric relation. When these periodontal proprioceptors are lost, the acuity of jaw position is reduced. This seems to place a greater responsibility upon dentists working with edentulous patients than upon those working with dentulous patients. However, this is not completely true because a malocclusion or an incorrect occlusal vertical dimension may hasten the day when the patient becomes edentulous. The principles of physiology must be recognized and respected whenever restorative work is done in the mouth. This is especially true when the patient is edentulous.

—Carl O. Boucher

THE ACADEMY OF DENTURE PROSTHETICS

I. LESTER FURNAS, D.D.S.

La Jolla, California

The Academy of Denture Prosthetics honored Dr. I. Lester Furnas with appropriate ceremonies at the annual banquet of its 1957 meeting in Columbus, Ohio. He was retiring as Secretary-Treasurer of the Academy after serving in this capacity for twenty-five years. Dr. Furnas is a charter member, has served the Academy in all of its elective offices, and was its President in 1936.

Dr. Furnas is a graduate of the University of Indiana, College of Dentistry, and after his graduation in 1910, he joined the faculty of the college where he served as an instructor and then as Professor of Prosthetics. In 1920, he moved to Western Reserve University, School of Dentistry at Cleveland, Ohio. He was Professor of Prosthetics at that institution until he retired from formal teaching in 1938.

He has lectured in 43 states, in Canada, and in Europe. He has had over 40 articles published in Dental Journals and was a coauthor of the American Textbook of Prosthetic Dentistry. His teaching, professional and civic activities, in addition to his service to the Academy, make him worthy of the honors he received.

THE NEED FOR BASIC IMPRESSION PROCEDURES IN THE MANAGEMENT OF NORMAL AND ABNORMAL EDENTULOUS MOUTHS

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THE DENTIST HAS A DISTINCT advantage in using a basic impression technique for complete dentures for both the normal and the abnormal mouth conditions.

The purposes and objectives of the complete denture impression should be: (1) *retention* of the completed denture, (2) *stability* of the completed denture, (3) *comfort* of the completed denture, and (4) *maintenance* of the *health* of the *supporting tissues.*

By basic impression procedures is meant the use of (1) standard metal impression trays, (2) similar materials, and (3) a definite technique for all types of cases with modification only for unusual conditions of the tissues and ridges. The dentist's concept of impression making should include proper border extension and coverage of the supporting structures.

The reasons a basic impression technique should be used for all mouths are:

1. All edentulous mouths have similar peripheral outlines (Figs. 1 and 2). It is generally agreed that the retention and stability of the completed dentures depends greatly upon proper border extension. The purpose of the border roll is to obtain a tissue seal that is wide and high enough to prevent dislodgment during function. Adhesion, cohesion, and atmospheric pressure are physical factors that aid retention.

2. In all edentulous mouths, the supporting structures consist of areas of soft and hard tissues which must be placed, and not displaced, to resist occlusal stresses. The placement of these tissues must be compatible with the biologic and physiologic tolerance of the tissues. Proper placement of the supporting tissues will provide proper stability.

3. The use of a basic impression technique will give the dentist more confidence and adeptness, and it limits the number of instruments and materials used. It likewise will provide the dentist with a thorough knowledge of the properties of the impression materials he uses consistently. In this way, overextensions, underextensions, hard tissue locks, overdisplacement, and impingements on resistant tissues will be avoided.

Read before the Greater New York Academy of Prosthodontics, New York University, College of Dentistry, Dec. 4, 1955.

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Essays and clinics on the subject of complete impression technique are presented in which modern impression materials—alginate, plastics, rubber, modeling compound, wax, zinc oxide and eugenol pastes, etc.—are used. Usually, a different impression technique is presented with each material, and a different material is suggested for each abnormal edentulous mouth.

Wright[1] wrote: "Occasionally, it may be necessary to extend a lower impression of a greatly resorbed mandibular ridge onto the reflected mucosa of the cheeks and lip to obtain denture support which the diminutive ridge cannot provide. Such atrophic ridges require *special procedures,* beyond the scope of this paper."

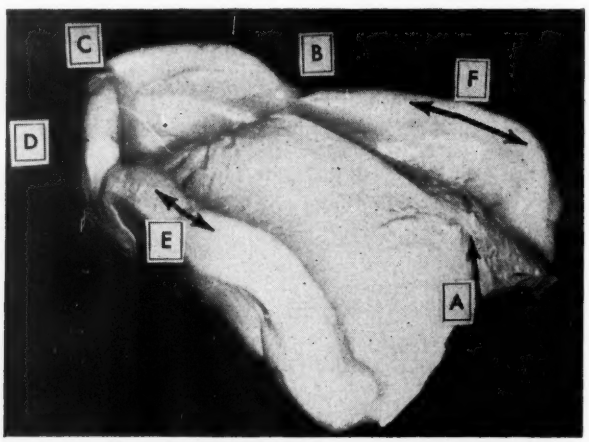

Fig. 1.—The anatomic outline and landmarks of the final maxillary impression. *A,* Fovea palatinae. *B,* Buccal frenum. *C,* Labial frenum. *D,* Anterior labial arch. *E,* Zygomatic process clearance. *F,* Buccal vestibule.

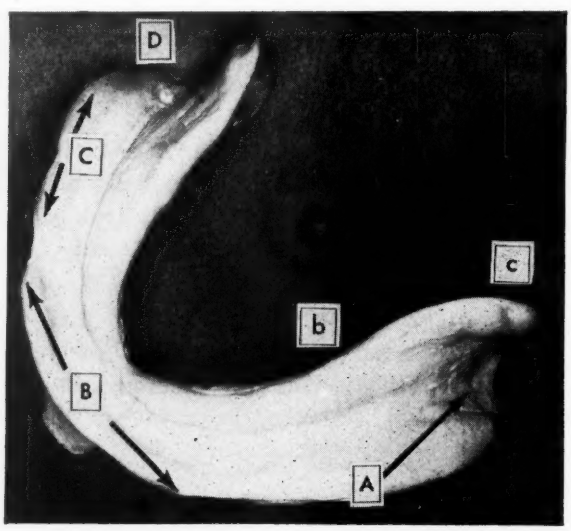

Fig. 2.—The anatomic outline of the final mandibular impression. *A,* Retromolar pad, *b-c,* The "S" lingual curve. *B,* Anterior labial arch. *C,* Mandibular buccal vestibule. *D,* Distobuccal corner.

Those who teach denture prosthetics understand how confused many dentists have become, going from one material and technique to another. The subject of complete dentures is a very difficult one, and many men have frustrating experiences in its practice. These men are easily turned from one impression technique to another. It is my contention that the operator can obtain successful results only from a thorough knowledge and clinical application of the anatomy, physiology, and histology of the edentulous mouth, clinical experience, skillful manipulation of the impression materials of choice, and the use of one sound impression technique.

Boucher,[2] in expressing his opinion of impression techniques, stated, "The great variation of methods, materials, objectives, and interpretation must leave the student of the problem with little but chaos in his mind as the result of his study."

It is not the intent of this article to persuade anyone to use the method or materials I employ in impression making. However, to make my premise intelligible, I will describe in an abbreviated form my technique[3] and the materials used. I use the open-mouth impression technique. Modeling compound is used for the initial impression, and a secondary impression is made with a free-flowing zinc oxide and eugenol paste, or rubber impression material. The modeling compound establishes the border outline and places the soft tissues over the seating area with as little overdisplacement as possible. The secondary impression relieves the areas of overdisplacement and establishes better border detail. Those who favor the so-called nonpressure type of impression claim that the use of modeling compound will produce a denture that will cause resorption of tissue regardless of whether a secondary impression is used. Clinically, this has not proved correct. I believe that the resorption of ridges is caused by occlusal disharmony, systemic factors, and improper nutrition, rather than by the impression technique.

I agree with Weinmann and Sicher,[4] who state, "The reactions of the denture-bearing areas in upper and lower jaws are proof of the high complexity of the problem of reaction of bone to pressure. It is well known that a great number of patients show little, if any, loss of bone in the jaws under well-constructed dentures. Even frequent reparative apposition has been observed in the areas of pressure. Though the intermittent nature of the pressure and its reflectory control are factors to be kept in mind, there is one more peculiarity of this bone to be considered. The alveolar bone receives its blood supply mainly from the interdental arteries that pass through canals in the interalveolar septa. Even after loss of the teeth, these arteries do not entirely disappear. Thus in contradistinction to other bones, the blood vessels of the alveolar ridges in an edentulous mouth receive their blood vessels mainly from the inside of the bone and only in part from periosteal vessels."

THE UPPER TRAY

A preliminary upper modeling compound impression is made, using Kerr's medium fusing compound in the N.Y.U. edentulous tray. These trays are thin, easily trimmed or bent, and are shallow enough to prevent impingement of the metal on the peripheral tissues. Two cakes of modeling compound are used so as

to have enough bulk with which to work. The initial seating is for centering and proper distribution of the modeling compound. The obvious excess is trimmed, and a groove is cut in the midline of the impression. Dry heat from a Hanau hand torch is applied to the modeling compound of the bearing area, and after tempering in a water bath at 160° F., the impression is reseated. This procedure will allow the modeling compound to flow toward the groove and over the borders of the tray. Since the flowing time and the flowing distance of modeling compound is limited, this will reduce the necessary time and distance of flow and thus help prevent overdisplacement of the tissues. The border roll is obtained by using Kerr's stick modeling compound and the usual muscle movements which activate the muscles of facial expression, the labial and buccal frenula.

The modeling compound impression is boxed and poured in stone. A double-thick shellac base is adapted to the cast to make a tray. Care is taken to make sure that the tray fills the buccal vestibule completely.

THE FINAL IMPRESSION

The tray is tried in the patient's mouth, and any indicated correction for over-extension, underextension, or impingements is made at this time. When satisfied with the retention and stability of this preliminary tray, five holes are drilled

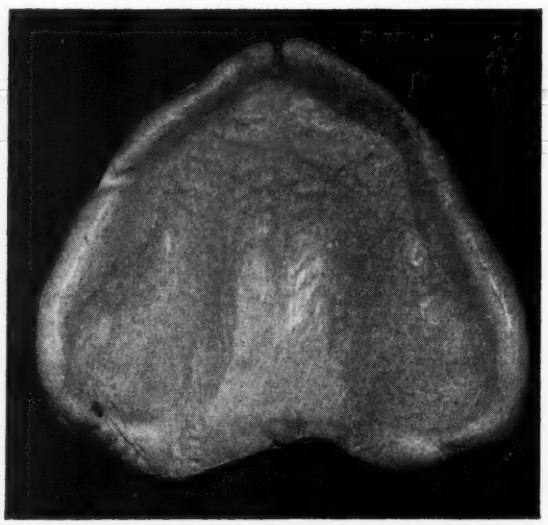

Fig. 3.—A final maxillary impression.

in the mid-palate region. These holes will provide the impression paste or rubber impression material with an escapeway and help prevent overdisplacement of tissues. The mouth is dried with gauze sponges. The impression paste is mixed in proper proportions and spread over the tray. The tray is gently seated in the mouth by jiggling it into position without pressure (Fig. 3).

The final maxillary impression is boxed and a stone cast is poured.

THE LOWER TRAY

The lower preliminary impression is made with the N.Y.U. type of edentulous tray, two cakes of Kerr's medium fusing modeling compound, and Kerr's Impression Wax Sticks (University of Iowa Formula). The initial seating, to center and properly distribute the modeling compound, should include all of the retromolar pads and as much of the sublingual space as possible. A groove is cut along the impression of the crest of the ridge and through the impression of the center of the retromolar pad. Dry heat is applied to the bearing areas by means of the Hanau hand torch. The impression is tempered in a water bath, with the temperature at 160° F., and then seated firmly in the patient's mouth. Then the buccal and labial borders are molded to conform to the reflecting tissues.

The buccal border opposite the retromolar pad is molded, after applying dry heat and tempering, by requesting the patient to close while holding the impression in place and exerting a downward pressure to counteract closing. This will activate the masseter muscle to muscle trim the distobuccal corner of the buccal flange. The middle buccal border, between the retromolar pad and the buccal frenum, extends laterally to the external oblique line. This area of the modeling compound impression is flamed (if the impression does not extend to the external oblique ridge, stick modeling compound is added), tempered, and the impression is reinserted. The patient is directed to draw the cheek inward while the impression is held in position. This movement activates the buccinator muscle to trim this portion of the border. The labial arches are then molded by activating the orbicularis oris and the labial frenum. Stick modeling compound is added to this area, flamed and tempered, and reinserted in the patient's mouth. The patient is directed to draw the lips inward and upward as if sucking on a straw.

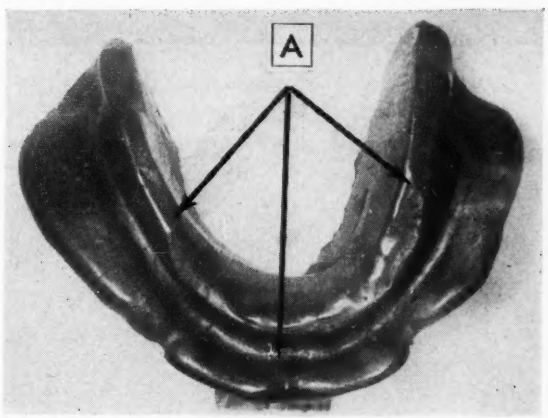

Fig. 4.—A preliminary mandibular impression. *A*, The modeling compound impression has had the lingual flange cut and prepared for the lingual wax trim.

The posterior lingual border is knife-cut until it is level with the mylohyoid ridge (Fig. 4). If this flange is short of the mylohyoid ridge, stick modeling compound is added. The entire *buccal surface* of the *lingual flange* is *knife-shaved*

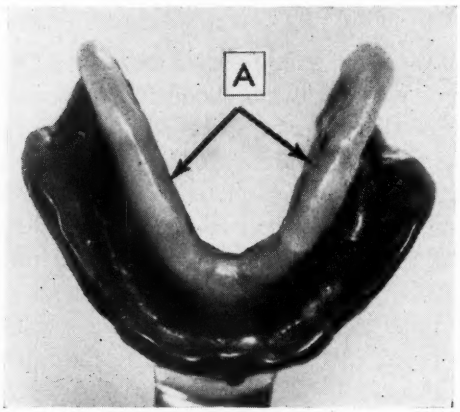

Fig. 5.—A completed preliminary mandibular impression.

Fig. 6.—A clear acrylic resin mandibular tray.

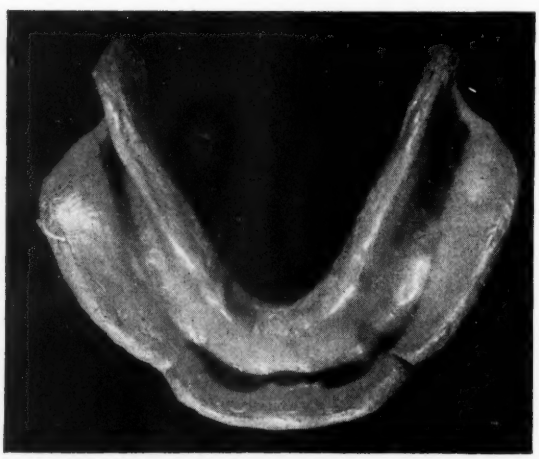

Fig. 7.—A final mandibular impression.

almost up to the height of the crest of the ridge to allow for a thickness of wax. The *sublingual* space, the area between the second bicuspids lingual to the mucolingual fold, is knife-shaved almost to the height of the crest of the ridge. The part of the tray covering the *retromolar pad* is also scraped away to allow for the wax. Kerr's low-fusing impression wax, in stick form, is attached to the modeling compound by dry heat. The retromolar pads and the area of the sublingual space are coated with a layer of melted impression wax. The impression is then immersed in the water bath at 140° F. and replaced in the mouth. It is held in position while the patient protrudes the tongue, moves the tongue from side to side, and up toward the palate. These movements activate the palatoglossus muscles, the superior constrictor pharyngeal muscles, and the mylohyoid muscles. The impression is removed after two to three minutes of lingual border molding and proper chilling (Fig. 5). It is poured in stone, and a clear acrylic resin tray is processed from this preliminary cast (Fig. 6).

THE FINAL IMPRESSION

The acrylic resin tray is tried in the patient's mouth, and corrections are made for overextension, underextension, overdisplacement, or impingements on resistant tissues. When satisfied with the retention and stability of the tray, the final impression is made with a zinc oxide and eugenol impression paste or a rubber impression material (Fig. 7).

In no way do I mean to imply that modeling compound should be used by every dentist for a preliminary impression. I know many who prefer to use wax, alginate, or plaster to obtain a cast on which to fabricate a tray for their final impression. Likewise, I do not contend that a zinc oxide and eugenol impression paste is the only way to obtain a satisfactory final impression. The rubber impression paste, alginate, plaster, and plastics are being used successfully. What I do say is that once we develop a successful complete denture impression technique, the basic steps and materials should not be changed radically. That does not mean that a dentist should not use a different preliminary or final impression material if he feels that it would benefit the patient. The new material would become part of the routine of impression making until a newer and better material became available.

Patients with the so-called *normal* or *usual* complete denture foundations constitute the great bulk of those seen in the average dental office. However, patients with abnormal, difficult, or unusual types of denture foundations are seen frequently enough to create problems. It is my contention that our techniques should not be changed in treating these patients, but they should be modified to meet the specific situation. I will discuss a *few* of the difficult edentulous types, showing the necessary modification of the basic impression technique.

HYPERPLASTIC AND HYPERTROPHIC RIDGES

A difficult type of denture foundation for the construction of a denture is one of a flabby, spongy ridge. The normal residual alveolar support has resorbed, and there has been an increase in the amount of soft tissue. This hypertrophic and hyperplastic tissue is easily displaced and difficult to record accurately in a

static state. It occurs most commonly in the upper jaw from the first bicuspid on one side to the first bicuspid on the other.

This condition can be treated by surgery when it is extremely severe. If surgery is not acceptable or indicated, the preliminary impression is made in the usual manner. Upon completion, the modeling compound is scraped away in the area of the pathologic tissue to a depth of approximately 3 to 4 mm. A cast is poured, and a tray is made. Holes are drilled in the altered section to prevent building up of pressure inside the tray. The final impression is made inside this tray, and the free-flowing paste will position this easily displaced tissue.

RESORBED MANDIBULAR RIDGES

In general, there are three distinct types of difficult foundations for mandibular dentures.

A. The type of foundation in which the mandibular ridge is almost completely resorbed, with just a rib of soft fibrous tissue along the crest of the residual ridge. This rib of tissue is easily displaced and can be a constant source of irritation if the impression is not recorded correctly (Fig. 8).

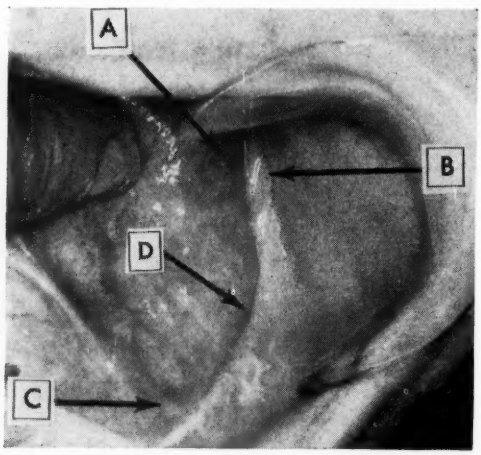

Fig. 8.—Anatomic landmarks. *A*, Retromylohyoid space. *B*, Retromolar pad. *C*, Sublingual space. *D*, Ridge of soft fibrous tissue.

The modeling compound-wax mandibular impression is made in the usual manner. The modeling compound over the crest of the ridge is relieved to a depth of approximately 3 mm., and a cast is poured. The clear acrylic resin tray, processed on the preliminary cast, will not contact the ridge crest. Three holes are drilled in the tray on each side in the areas of the ridge crest to prevent a building up of undesired pressure. The final impression is made inside the acrylic resin tray, and the free-flowing paste will allow the soft tissue along the crest of the ridge to place itself.

B. The type of foundation in which the mandibular ridge is almost completely resorbed, with a spiny ridge of dense bony tissue along the crest of the residual ridge (Fig. 9). This condition is probably caused by the unequal rate

of resorption of the cortical and cancellous bone. The tissue over the spiny ridge is very thin, and a minimum amount of pressure causes pain. This type of foundation is often associated with a prominent knife-edged mylohyoid ridge. The mylohyoid ridge is covered with a thin layer of soft tissue which is easily displaced with subsequent irritation and extreme discomfort.

The modeling compound impression is made in the usual manner. The modeling compound is scraped away along the crest of the ridge to a depth of approximately 3 mm. The modeling compound in the posterior lingual flange, which extends just to the mylohyoid ridge, is relieved on the tissue side to a depth of approximately 2 mm. The physiologic wax is added to the modeling compound, and the final portion of the preliminary impression is formed. The cast is poured, and the area of the mylohyoid ridge is relieved with 0.001 inch tin foil. Thus, the spiny crest of the ridge is relieved in the modeling compound, and the spine of the mylohyoid ridge is relieved by the tin foil on the cast. The clear acrylic resin tray, constructed from the preliminary cast, will not contact the crest of the ridge or the tissue over the mylohyoid ridge. The final paste impression is made inside the clear acrylic resin tray. The master cast is poured. The knife-edged ridge crest is relieved with 0.001 inch tin foil. The forces of mastication will be exerted along the sides of the ridge rather than on the crest.

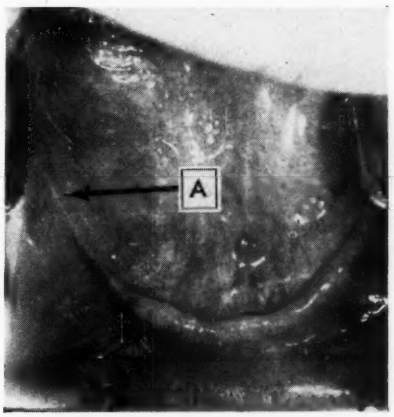

Fig. 9.—*A*, A sharp spiny ridge crest.

C. The type of foundation in which the ridge is flat or concave (Fig. 10,*A*). The impression of the lingual border will be recorded accurately with the impression wax, even though the residual ridge has resorbed to the level of the attachments of the floor of the mouth. This type of foundation should not require any alteration or modification in the impression technique, except where the mylohyoid ridge becomes a disturbing factor. This situation is handled as described previously. The coverage of the denture-bearing area will be the same as for an average foundation. The supporting structures have changed, but the muscles of the border regions still function normally and will mold the borders of the impression. The ridge directly anterior to, and including, the retromolar pads does not resorb to any appreciable extent. Therefore, the distolingual flange on the

medial side of the ramus of the mandible, opposite the retromolar pad, will generally be sufficiently deep to prevent lateral displacement of the denture. The space in which the distolingual flange rests is called the retromylohyoid space. When this sulcus does not exist in these badly resorbed mandibular edentulous mouths, the prognosis for retention is poor.

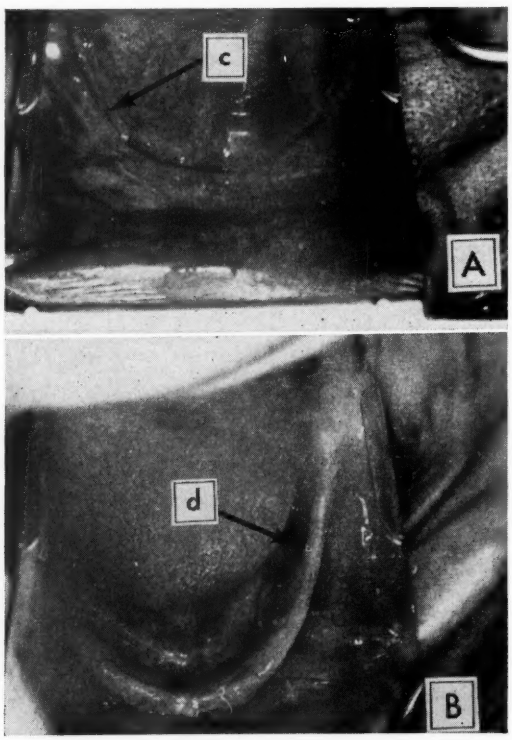

Fig. 10.—*A,(c)* A badly resorbed mandibular ridge. *B,(d)* An undercut on the lingual side of the ridge.

THE UNDERCUT MANDIBULAR RIDGE

The undercut is usually on the lingual side of the mandibular ridge (Fig. 10,*B*). This condition is caused by the extraction of teeth which were in lingual version for many years. Surgical removal of this lingual bone is not necessary or desirable. It is not necessary because the impression can be made by seating the impression from back to front and removing the impression from front to back and then out. Surgery is not desirable because it would cause a flattened ridge.

THE TORUS PALATINUS

The torus palatinus is a hard, raised bony mass in the median portion of the palate. It is covered by a thin layer of soft tissue. The median portion of the palate has been relieved traditionally, regardless of whether a torus was or was not present. The relief should be used only when a torus palatinus can be seen

or palpated. Sometimes, the torus may be so enlarged that it presents a problem in denture construction. In some instances, surgery is resorted to when the patient is in good health and acquiescent.

The upper preliminary impression is made in the usual manner. The modeling compound in the area of the torus is relieved generously, and a cast is poured. A tray is adapted and "fitted" in the mouth in the usual manner. The secondary impression is made and the master cast is poured. The torus palatinus is relieved by cementing medium gauge relief metal on the cast. The metal is carefully contoured and usually extends anteriorly to cover the incisive papilla.

THE TORUS MANDIBULARIS

The torus mandibularis is a bulbous mass of bone covered by a thin layer of soft tissue that is usually found in the area between the first and second bicuspids on the lingual slope of the mandibular ridge.

The torus mandibularis should be removed surgically when it is sufficiently extensive, if the patient's health permits. When it is not too prominent, or where surgery is contraindicated, the following treatment is followed:

The modeling compound-wax impression is made in the usual manner. A cast is poured, and the area of the torus is relieved with relief metal. The final impression is made, and the master cast is poured. Relief metal is cemented to the cast in the area of the torus. The denture will not contact this bony mass, and a seal in the floor of the mouth will be maintained.

REFERENCES

1. Wright, Walter H.: A Method of Securing Correct Impressions, J.A.D.A. **27**:1587, 1940.
2. Boucher, Carl O.: A Critical Analysis of Mid-Century Impression Techniques for Full Dentures, J. Pros. Den. **1**:472-491, 1951.
3. Klein, Ira E.: Complete Denture Impression Technique, J. Pros. Den. **5**:739-755, 1955.
4. Weinmann, Joseph, and Sicher, Harry: Bone and Bones, Fundamentals of Bone Biology, ed. 2, St. Louis, 1955, The C. V. Mosby Co., p. 137.

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AN EMERGENCY TEMPORARY DENTURE

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THIS TECHNIQUE IS INTENDED for use as an emergency measure to be used when a complete upper denture has been lost or has been damaged beyond repair. Also, it can be modified for other types of replacement. It is only meant to serve the patient until a more permanent type of denture can be constructed at the convenience of the patient and the dentist.

The first step consists of obtaining an alginate impression of the edentulous ridge and the surrounding area. A cast is poured up, using a mixture of one-half cast plaster and one-half impression plaster. The purpose of this mixture is to shorten the setting time. After the mixture has set, it is separated from the impression, and an outline of the border of the denture is marked on the plaster cast with a soft pencil (Fig. 1). The palatal seal area is scraped lightly with a sharp laboratory knife. A coat of liquid tin-foil substitute or petroleum jelly is applied to the cast.

THE DENTURE BASE

Self-curing pink acrylic resin powder is applied to the cast, a small section at a time, by spraying the dry acrylic resin powder from a polyethylene bottle with a very small opening. The acrylic resin monomer is then applied with a dropper until the powder is saturated. This process is repeated over the entire area of the cast outlined in pencil until it is completely covered. The acrylic resin is then built up as before, layer upon layer, until an adequate thickness has been developed. The resin is allowed to cure for approximately 10 to 15 minutes or until it is hard (Fig. 2). The denture base is separated from the cast by inserting a laboratory knife between the acrylic resin base and the cast. The denture base is examined, and thin spots can be built up with acrylic resin by using the paint-on technique. The base is then trimmed to the pencil finishing line which has been transferred from the cast to the tissue surface of the denture base. The palatal surface can be polished at this time, or it can be done in the final polishing. The base is tried in the mouth, and the final trimming is accomplished.

THE POSTERIOR OCCLUDING SECTIONS

Establish as nearly a normal occlusal vertical dimension as possible. This can be determined in the same manner as for a permanent type of denture. Place a mark on the tip of the nose and one on the point of the chin. Cause the patient

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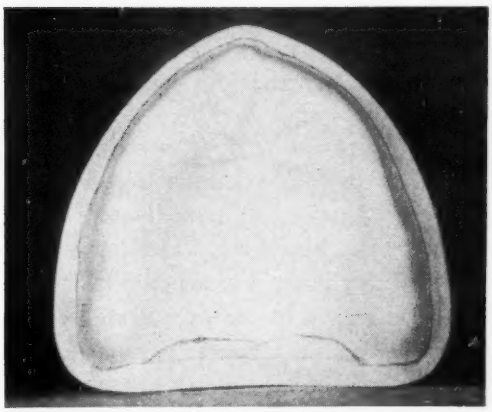
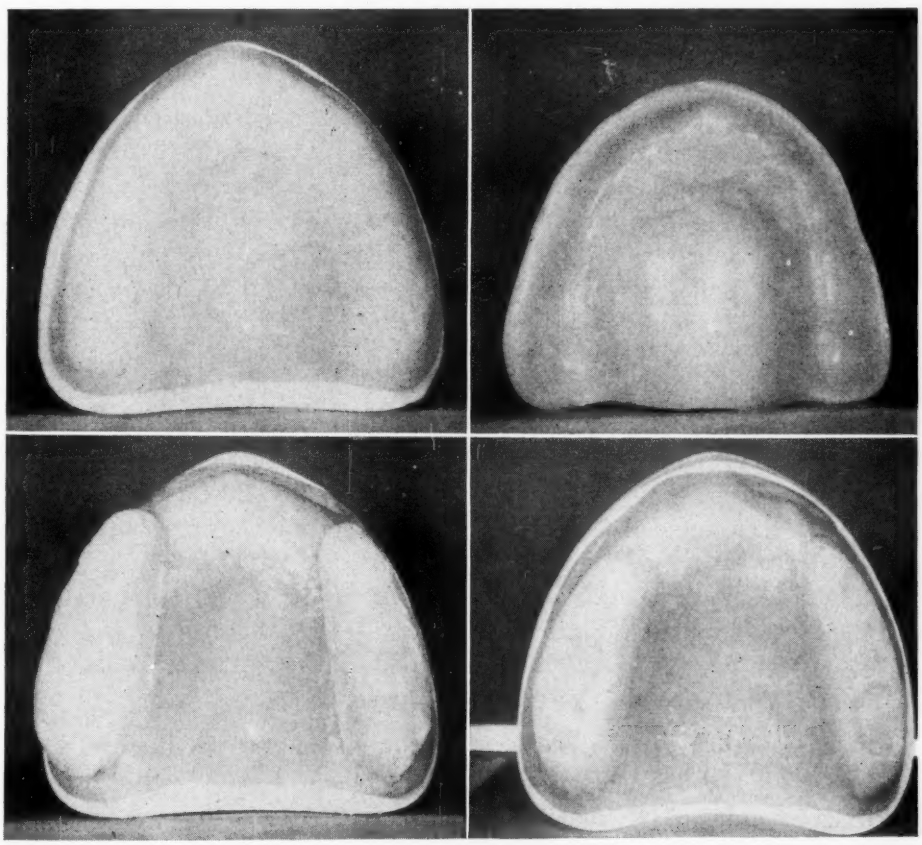


Fig. 1.—The border of the denture is marked on the plaster cast with a soft pencil.

A. Fig. 2. *B.*



A. Fig. 3. *B.*

Fig. 2.—*A*, The denture base on the plaster cast before removal. *B*, The denture base separated from the plaster cast.

Fig. 3.—*A*, The denture base with tooth-colored acrylic resin in the posterior segments before being occluded with the opposing teeth. *B*, The acrylic resin segments in the mouth after being occluded with the lower teeth and after the excess has been removed.

to get his mandible in rest position, and measure the distance between the two dots. Reduce this distance 3 mm. to allow for interocclusal clearance. The resultant measurement is recorded on a Boley gauge or calipers and put aside for use later.

A sufficient amount of self-curing tooth-colored acrylic resin of a suitable shade is mixed and allowed to cure to a doughy consistency. The ridge surfaces of the denture base, distal to the cuspids on both sides, is then moistened with acrylic resin liquid, and the partially set tooth-colored acrylic resin is placed on the denture base in those areas (Fig. 3,*A*). The lower teeth are lubricated, the upper denture base with the acrylic resin attached is placed in the mouth, and the patient is instructed to close slowly to the previously determined vertical dimension as recorded on the caliper or Boley gauge. The denture base is removed from the mouth after one minute, and the resin is allowed to set. This produces the desired occlusal height and interdigitation in the posterior segments. The excess tooth-colored acrylic resin is removed, and the base is replaced in the mouth in order to recheck the vertical dimension. Any discrepancies can be corrected by adding or removing acrylic resin in the posterior region (Fig. 3,*B*).

THE ANTERIOR TEETH

The denture base is replaced in the mouth and the six anterior teeth are selected to match the patient's lower teeth. If stock teeth are not available, tooth-colored acrylic resin can be added and carved later, or celluloid crown forms can be filled with acrylic resin to form the teeth. The teeth are ground-in where necessary, set on the denture base while it is in the mouth, and occluded with the lower teeth. They are fixed to the base by means of sticky wax placed on the labial surface (Fig. 4,*A*). The denture is removed and pink self-curing acrylic resin is applied to the lingual surface of the base and teeth by the paint-on method. This attaches the teeth to the denture base (Fig. 4,*B*). After the new resin on the lingual surface has set completely, the sticky wax is removed from the labial surface, and the paint-on technique is used to attach the teeth to the labial surface of the denture. After sufficient time is allowed for the resin to cure, the denture and teeth are trimmed, shaped, and the posterior segments are carved to simulate teeth. The denture is polished for insertion in the mouth. Final adjustments of the occlusion, borders, postpalatal seal, and incisor tooth length are made at this point, and the denture is complete (Fig. 5).

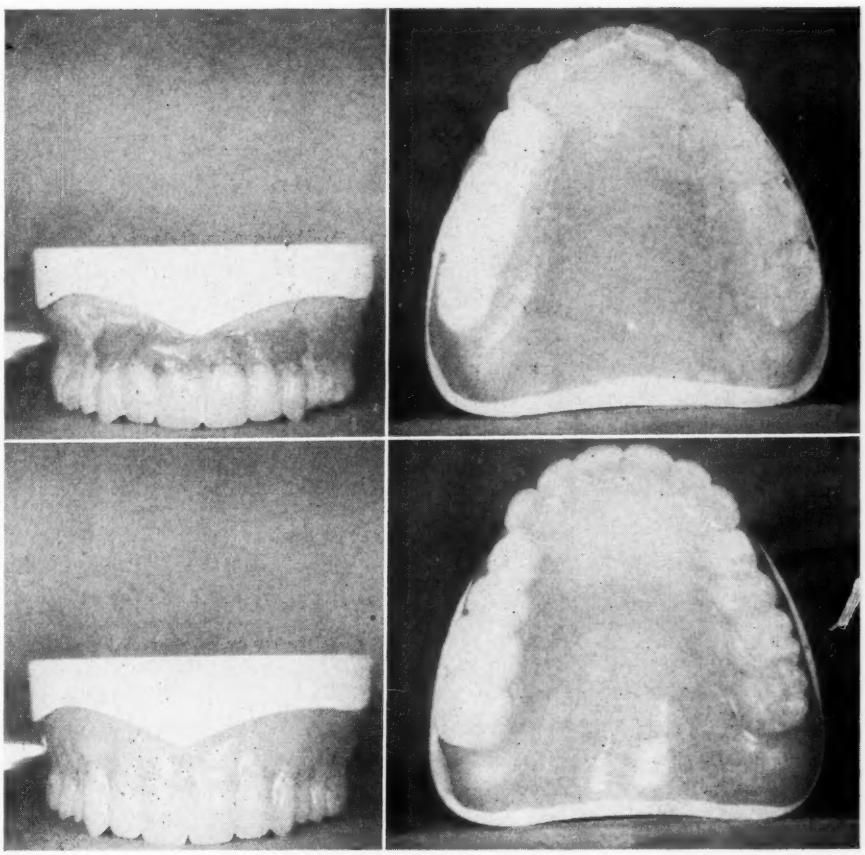
PARTIAL DENTURES

This procedure can be modified so that temporary partial dentures can be made quickly. The only modification is the addition of clasps where necessary. Clasps can be made quickly from 0.030 stainless steel orthodontic wire. The clasps are bent, and suitable extensions are provided for embedding into the acrylic resin. The clasps are held in place by attaching them with sticky wax to the labial surface of the teeth that are to be clasped. Otherwise, the procedure is the same as for temporary complete dentures.

COMPLETE UPPER AND LOWER DENTURES

Where both complete upper and lower dentures are to be constructed, the procedure is essentially the same, except that in determining the occlusal height and inclination of the upper posterior teeth, we select a vertical height arbitrarily, using the ala-tragus line as a guide, then set up the anterior teeth, and make the final adjustments in the mouth by adding or removing the resin on the occlusal surfaces of the posterior segments. Once the upper denture is completed, the lower denture is constructed in the same manner, using our upper denture as the guide.

A. Fig. 4. *B.*



A. Fig. 5. *B.*

Fig. 4.—*A*, The anterior teeth fixed to the denture base with sticky wax. *B*, The lingual surfaces of the anterior teeth attached to the denture base with quick-curing acrylic resin.

Fig. 5.—*A* and *B*, The finished denture.

IMMEDIATE DENTURE

This technique can be used also for the fabrication of an immediate complete denture. The procedure is essentially the same, except that a partial denture base covering the edentulous area is made first, then the posterior tooth-colored

acrylic resin occluding surfaces are added, and the occlusal vertical dimension is determined. Then the partial base with the occluding posterior segments in place is returned to the cast, the remaining natural anterior teeth are removed from the cast, and the necessary additional denture base is added to the cast to cover the entire edentulous ridge. After this has cured, the anterior teeth are fixed to the base with self-curing acrylic resin, and the denture is trimmed and polished and ready to be inserted when the teeth are extracted.

This technique can be used also for the construction of "bite planes." Orthodontic wire is bent to fit the cast where indicated. The wire is held in position by attaching it to the labial surfaces of the teeth involved with sticky wax. Then the acrylic resin is applied as in the other situations and allowed to cure. After curing, the appliance is removed from the cast and trimmed and polished.

SUMMARY

A technique for constructing emergency temporary dentures has been described. The procedures are adapted easily to other situations and the necessary modifications have been described.

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THE TRANSOGRAPH AND TRANSOGRAPHIC ARTICULATION

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INTRODUCTION

TWO ARTICLES WERE PUBLISHED in the *Dental Digest* in 1951 which interested me. The first was "Centric and Hinge-Axis,"[1] and the second was "The Bennett Movement."[2] The latter one mentioned the fact that an articulator had been built which was able ". . . to inject the Bennett movement while operating in conjunction with the asymmetrical axal center or hinge-axes principle" and, in addition, ". . . accepting instantly and perfectly wax bites of widely varying thicknesses and bite depths on any given dentulous case."

The United States Patent Office awarded the Transograph this trade mark: "Jaw Recorder and Duplicator."* The dictionary[3] states: *trans,* a Latin prefix meaning across, beyond, through; *o-,* an ending for the first element of many compounds; and *graph,* a word element from the Greek meaning an apparatus for drawing, writing, or recording; in other words, a writing of jaw movements carried over to an articulator. The question that naturally comes to mind is: what does this articulator claim to do? Its whole purpose is to record and duplicate functional jaw movements. Function is difficult to copy. Most of us still insist that it is impossible to copy jaw function on any machine. The inventors claim, however, to literally take the patient's head and place it upon the laboratory bench.†

Let me first present some of the historical background which was responsible for the development of the articulator. To Beverly B. McCollum and the Gnathological Society goes all the credit for the principles upon which this theory and technique are based.[4, 5] They are the principles of (1) the rotational control centers, (2) the cranial plane, (3) the Bennett movement, and (4) the envelope of motion. There is a large school of thought which feels that these principles are sound.

THE ROTATIONAL CONTROL CENTERS OR HINGE AXES

This concept stresses the uselessness of a centric relation record in the following line of reasoning.[1, 6] Every rotating body turns upon some fixed or imaginary line, whether it be the earth or a small wheel spinning upon an axis going through its hub. The condyles, which are irregular bodies, have imaginary hinge

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*Harry L. Page: Personal communication, Feb. 11, 1956.

†Harry L. Page: Personal communication, Feb. 11, 1956.

axes which pierce them transversely, horizontally, and sagittally (Fig. 1). These axes direct the arcs through which the condyles rotate. The condylar hinge axes must be first found and duplicated upon an articulator before any centric relation record can be used, otherwise the use of this centric relation record or needle point tracing will serve only to relate the flat occlusion rims at one static position. Should the articulator be moved even the slightest degree vertically, horizontally, or transversely, the results will be inaccuracies. In addition, should the flat occlusion rim surfaces be changed to irregular cusp surfaces without accurate hinge

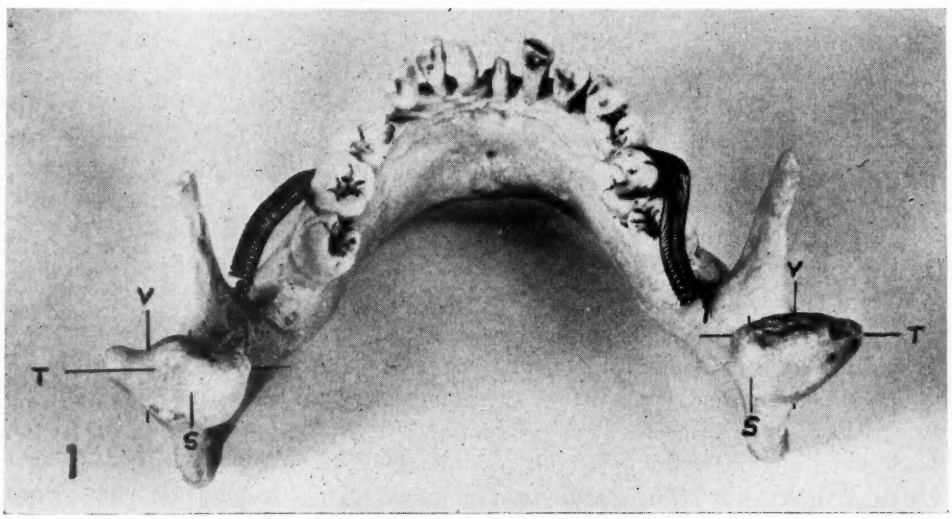

Fig. 1.—The condylar axal centers are independent of each other. *T*, Transverse; *V*, vertical; *S*, sagittal. (From Harry L. Page, Dental Digest, April, 1956, p. 163.)

axis controls, these results will be inaccurate; in other words, centric relation will hold only as long as no motion takes place—but should function begin, centric relation is of no value.

The arcs of closure for each mouth are different. They depend upon the rotational centers of the condyles. Looking at the head from the rear, if the condylar axis on one side is higher than on the other side, then, regardless of the perfection of the occlusion rims and needle point tracing, the teeth will touch only on the side in which the articulator and condylar hinge axis coincide, whereas, on the opposite side, they will be separated.

When using a centric relation record to mount casts, how often do we hear the expression, "The recording wax should be thin and the cusp imprints should be shallow"? If the wax interocclusal record is too thick or the cusp imprints too deep, we are fearful that the record will not be correct. With a thin record, we are hopeful that even though the casts are not mounted on the closure axes, we are close to them. "At no time, regardless of the type of face-bow used, is it safe to make centric relation records at an opening greater than the rest position

of the mandible."[7] Transographics states that if this is true, then is not that an admission of the fallacy of centric relation, of the fact that it is a static record only for that special vertical position, and that it is immediately destroyed when functional chewing begins? If the diagrams are drawn[8] representing the paths of tooth travel for dentulous and edentulous cases mounted by means of centric relation records, it will be shown that the diverging arcs of closure will cause cuspal interference, but, in the edentulous case, the interference will be heaviest at the cusp tips and none at all at centric relation (Fig. 2), whereas, with a dentulous case, the interference will be none at all at the cusp tips, but a great deal at the final closure position (Fig. 3). In the edentulous case, the wax rims contact at the static position of centric relation, and the teeth set up from this point had the cusps open 2 mm. It was, therefore, at the start of closure that the arc

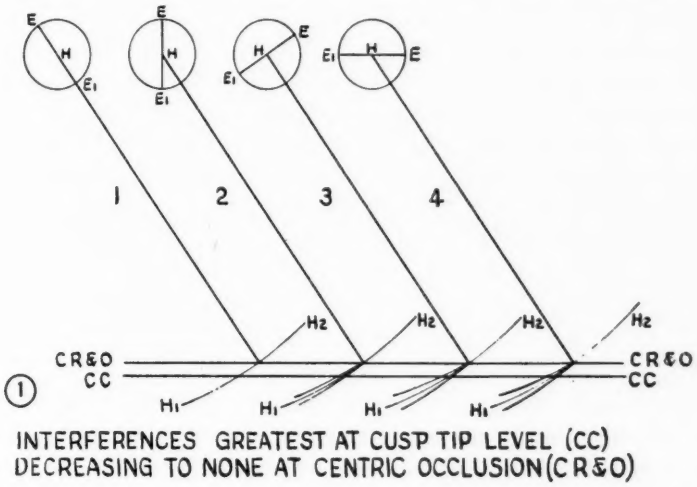

Fig. 2.—The fallacy of centric relation in the edentulous case. (Courtesy of Harry L. Page and Dental Digest.)

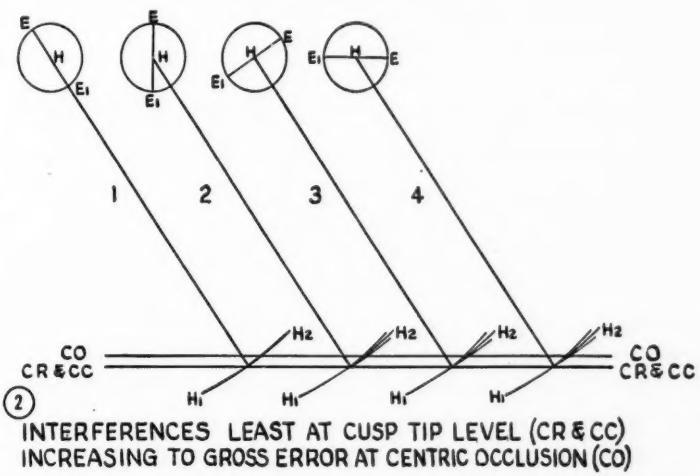

Fig. 3.—The fallacy of centric relation in the dentulous case. (From Harry L. Page, Dental Digest, Jan., 1955, p. 20.)

was different; whereas, in the dentulous case, the centric relation record was made with the cusps just out of contact. Therefore, the clash could come after the cusps closed the 2 mm. necessary for final closure and, at final cusp contact, centric relation would be a destructive position.

This is the reason that a thick centric relation wax is not advisable when using conventional articulators. However, in Transographics, "when using hinge-axes and cranial planes that have been proved correct, there is no need to fear the mechanical difference in the mouth and instrument closure paths or the incorrect occlusion that are so disastrously common to centric relation mountings."[8]

THE BENNETT MOVEMENT[2, 10, 11]

There are several components to jaw motion, each of which must be recognized and incorporated in the articulator. The Bennett movement has been looked upon as a definite bodily side shift as the jaw moves laterally. It has always been accepted as a component of lateral jaw motion. It has been called the "power movement," and it has been said to have more influence upon the articulating surfaces of the teeth than any other component of jaw motion.[4] In Transographics, the Bennett movement is not considered as a component of lateral motion, but rather as a component of "natural functional movements, the major one of which is the vertical movement."[11] It is said to be due to the asymmetry of condylar positions, sizes, and shapes. It is explained as follows:

If the condylar hinge axes are asymmetrical, then there will be small collateral movements upon closure. The condyles are loosely encapsulated. Therefore, there can be a bodily shift in any single plane or in all three planes simultaneously, with condylar movement in the same or in a different direction. Then again, there are differences in the ramus and body length of one side of the mandible as compared to the opposite side. This will cause divergent centers and radii and will force a collateral translatory movement upon every opening and closing. Using this knowledge, the Transograph is said to have incorporated in it a Bennett movement with the shift taking place automatically while operating in conjunction with the asymmetrical hinge axis principles.

THE ROLE OF THE TEMPOROMANDIBULAR LIGAMENT

The condyles use the restriction of the temporomandibular ligaments as radii and swing upward and sometimes forward to attain their fulcral position on the posterior inferior slope of the articular eminence (Fig. 4). They are held in their fulcral position by these ligaments while the internal pterygoid muscles, the anterior part of the temporal muscles, and masseter muscles act in power closure. This ligament also helps bear the heavy tension of power closure. When a strong force attempts to retrude the mandible, the temporomandibular ligament arcs the condyle upward and occasionally slightly forward, while the body of the mandible moves backward. When relaxed, the condyles drop bodily to their physiologic rest position. The conventional theory is that, from this rest position, the mandible simply rotated to its fulcral position. However, if a hinge-bow is observed closely when it is used to locate the hinge axis, it may be ob-

served that, when the mandible drops to its rest position, translation, and not rotation, takes place. It appears from this that the physiologic rest position should not be used as a starting point in mounting casts upon an articulator.[12, 14]

PLANES OF THE HEAD AND THE HINGE AXES

The different planes of the head and hinge axes have been stressed by others, but this concept caused additional attention to be focused upon them. There are

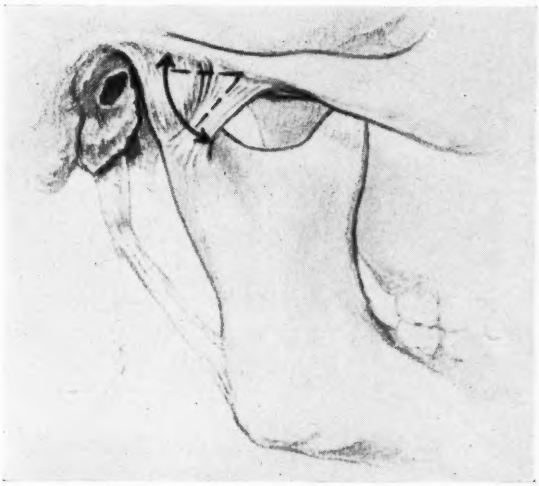

Fig. 4.—The temporomandibular ligament, condylar guide, and anchor in a power closure. (From Harry L. Page, Dental Digest, Jan., 1955, p. 20.)

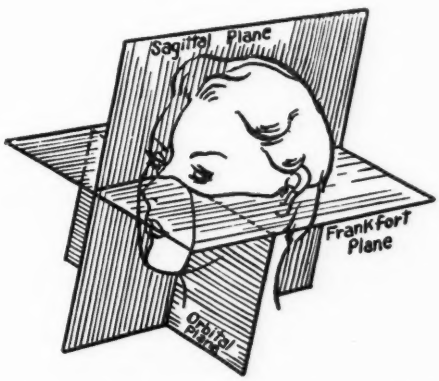

Fig. 5.—Three planes of space as related to the head. (From J. A. Salzmann, Principles of Orthodontia, J. B. Lippincott Co., 1943.)

three planes which are used in describing jaw movements in the head, namely: (1) sagittal, (2) transverse, and (3) horizontal (Fig. 5).

In kinematics, there are rotations which are controlled by hinge axes. There are three different kinds of axes which are found in the head: (1) vertical

axes, (2) transverse axes, and (3) sagittal axes. These three axes control rotation in different planes (Fig. 6). Transverse axes control rotation in the sagittal plane. Vertical axes control rotation in the horizontal plane, while sagittal axes control rotation in the transverse plane. In all, there are eighteen axes in the skull. Three are in each condyle, three in each ramus, perhaps, near the mandibular foramen or nearer to the gonial angle, and, finally, three in each articular eminence, described by Hjortsjö as "axes of movement passing through the center of the articulator tubercle and about which the tuberculum rotated."[15]

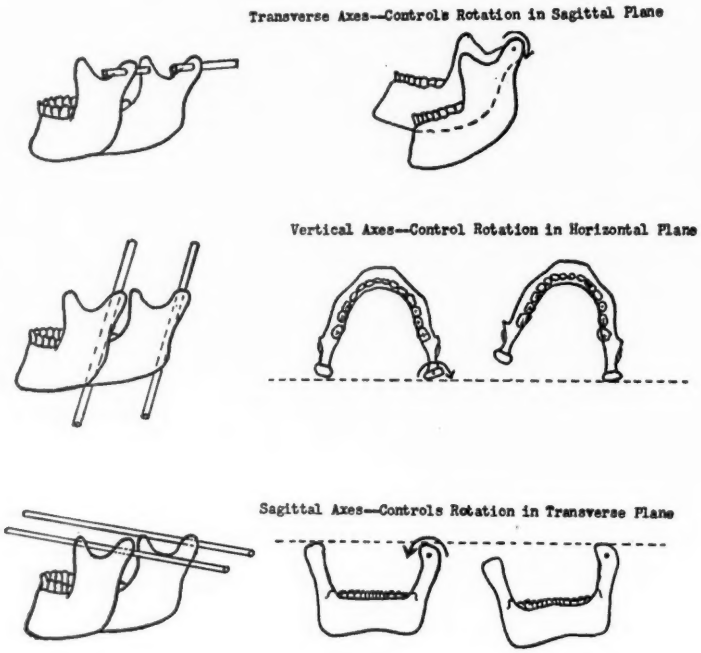
Transverse Axes—Controls Rotation in Sagittal Plane
Vertical Axes—Control Rotation in Horizontal Plane
Sagittal Axes—Controls Rotation in Transverse Plane

Fig. 6.—The transverse, vertical, and sagittal axes. (Modified from Hjortsjö, Acta odont. scandinav. 2:17-18, 1953.)

AXAL CENTERS VERSUS POINT CENTERS

Axal centers versus point centers is another very controversial subject brought to the fore by this concept, which is described[13] as follows:

"A hinge axis has been defined as . . . a theoretic axal center that pierces a condyle transversely."[16] Each condyle has its own axal center, and this is not a point center. Each axal center is independent of the other. They are asymmetrical. The claim is made that the Transograph is the only articulator which has axal centers and that other articulators, regardless of their shape, including the Gnathoscope, have a mechanical connection between their two bearings. This constitutes a solid axis. The condyles have their junction in the symphysis which is an offset point. The Transograph has its condylar bearings joined only by means of casts that represent and duplicate the patient's maxillary and mandibular

arches (Fig. 7).[10]* It is also denied that a hinge axis is scientifically constant to the mandible or to the articular disk even in simple rotation, not to mention a combination of rotary and lateral movements. The irregular condyles make it

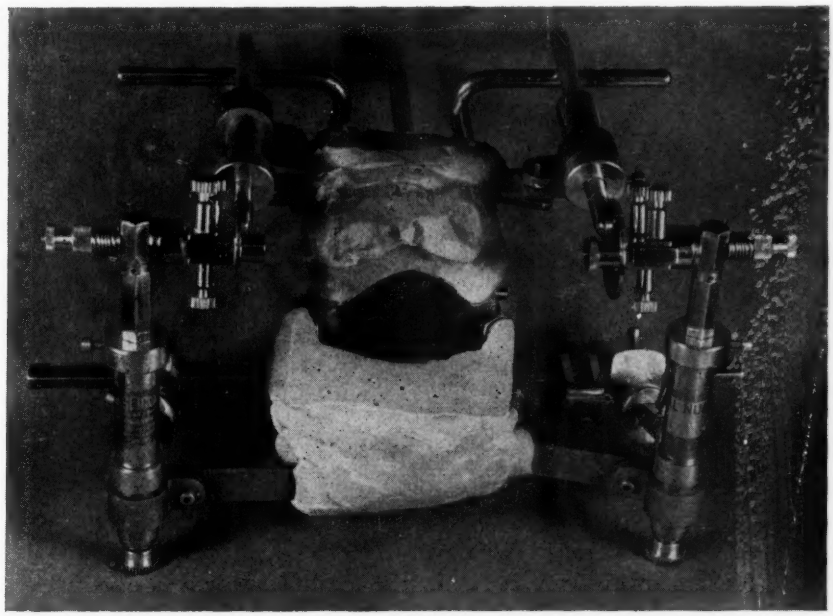

Fig. 7.—A rear view of the Transograph showing the split axes joined only by the casts.

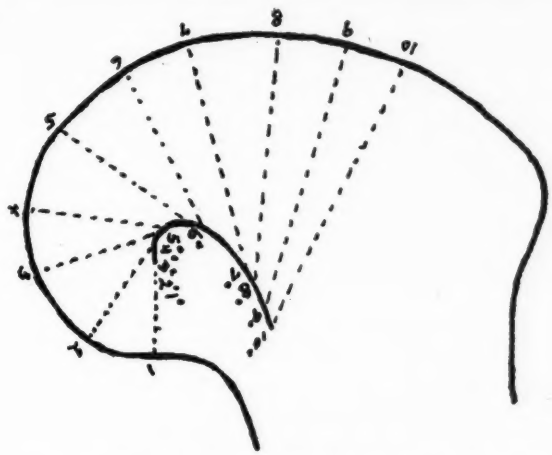

Fig. 8.—A spiral joint (femoral condyle in profile) in which the axis of movement is not fixed but changes with its position. The various circle centers are situated along a curved line, the evolute. Such is the case in the upper division of the temporomandibular joint. This suggests that the transverse hinge axes are not scientifically constant to the meniscus. (Redrawn from Fick, 1911.[21])

impossible for the various individual axes to be constant, even in simple rotation.[19] Hjortsjö[18] found that in extensive rotation of the condyle, with no forward movement, the result of the locus of the consecutive axis centers took the form of an evolute curve (Fig. 8). The slope of the fossa resembles somewhat a parabolic

*Harry L. Page: Personal communication, April 19, 1956.

curve when viewed in the sagittal plane according to the same investigator. This suggests that the transverse hinge axis is not constant to the mandibular meniscus during combined rotary and lateral movement.[19-21] However, both Page and Hjortsjö state that this inconstancy is slight during jaw motion within the terminal functional orbit.[20]* This is contrary to the concept of Gnathology which maintains that the hinge axis is constant to the mandible.[22]

The vertical axes control motion on the horizontal plane, but there is no definite way known to locate them in the skull. The Gnathoscope uses its so-called anterior envelope of motion to have the styli move along the border paths, while the posterior mechanism of the instrument is adjusted to these movements. In that way, the vertical axes are supposedly located. In Transographics, an attempt is made first to locate the vertical axes of the condyles inward from the skin three-eights of an inch (Fig. 9). It is admitted that this is arbitrary, but the claim is made that it is close. In making the face-bow record, the pins are kept close to the skin in order to capture the intercondylar width as accurately as possible.

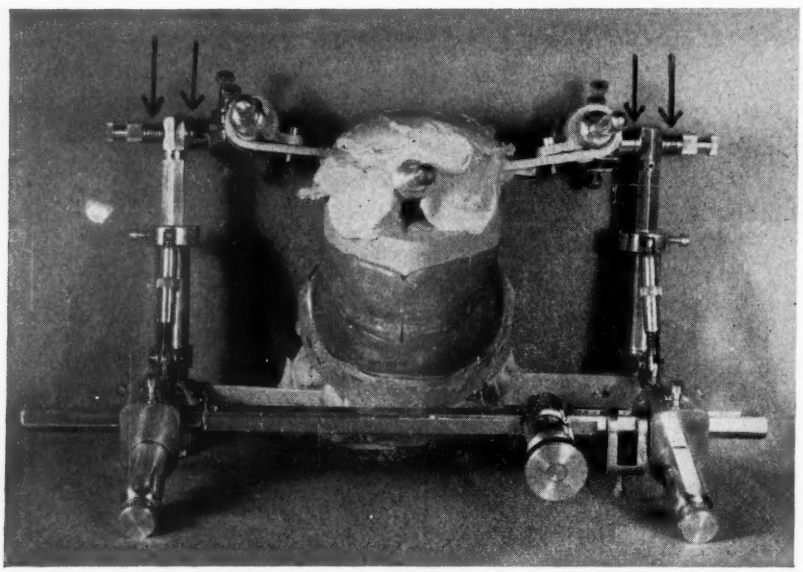

Fig. 9.—A metal plate, ⅜ inch thick, used to locate the condyles inward from the skin. Springs on the transverse axes relieve the instrument of torque.

It is stated that the movements in the horizontal and transverse planes are small as compared to movements in the sagittal plane, but these movements in different planes must be duplicated on the articulator, and this cannot be done with point centers and a rigid intercondylar axis. The only object in which there can be a common center for all planes is a perfect sphere. The condyles are irregularly shaped. Because of their irregular shape, the articulator must be provided with asymmetrical axal centers individual to each condyle. According to its inventor, the Transograph makes provision for this in its broken axis. The jaw provides for these collateral movements by moving bodily. It can do this

*Harry L. Page: Personal communication, March 14, 1957.

because of the looseness of its suspension in the capsular ligament sling and the accessory muscles. *The bone does not bend as so many have inferred.*[16]

The condyles are not rigidly controlled as in an articulator. They can slide bodily along paths produced as a result of these asymmetrical rotational centers. The articulator must be flexible enough to arc in order to reproduce these collateral shiftings in three different planes which cannot have a common control center. With this slight bending or torque, these movements, which are controlled by the sagittal and vertical axes and take place along the transverse and horizontal planes, will occur. In the Transograph, it can be detected by observing the slight twisting of the instrument ". . . a sort of mechanical protest against being forced to rotate upon untrue bearings."[16] Page states: "That the Transograph flexes is often cited against it by those who have no understanding of the principles involved. It would help them if they realized that the jaw, too, is a sensitive apparatus. It makes many collateral movements such as the Bennett during normal function. While a mechanism might be built that would copy these collateral shifts, it is much simpler and just as effective to use flexing to produce what are commonly known as mechanical equivalents. Proof that these are true equivalents lies in the constant acceptance by the visibly flexing Transograph of tight-fitting wax matrices made in the mouth at various occlusal separations.

"When the instrument is chewing, there is considerable torque created by the axal centers of rotation. To relieve the instrument, springs were put on the transverse axes so that they would slide back and forth in their bearings. It turned out that, in some cases, the combination of torquing and guidance from the cams caused the vertical hinge axes to trace their correct positions for all degrees of horizontal movement; axes moving inward with the opening and outward with the closing stroke."*

REFERENCE PLANES

Twenty-five years ago, McCollum[4] established what he called an axis orbital plane as a necessary part of the process of mounting casts on his articulator, either for dentulous or edentulous cases. About the same time, Wadsworth drew a line from the condyle to a point near the corner of the eye for use as a reference. Simon used a tragus orbital plane as a reference for mounting casts. McCollum established the axis orbital plane by lines running from the hinge axes on the right and left sides to points on the floor of each orbit, which he later transferred to one point on the side of the nose corresponding to the right orbit point. The axis orbital plane extends from the axes to the infraorbital points. He said the plane was horizontal when the body is erect and that, with its establishment, the slant of the anterior teeth may be established and an idea of the long axis of every tooth on a cast may be obtained. He said, also, "The slant of the condyle path [of the instrument] is not relatively the same, but is then identical with the slant of the path in the face . . . the proper plane of occlusion may be established . . . without the establishment of the axis orbital plane . . . the teeth stand one chance in a million of being properly placed."[4]

*Harry L. Page: Personal communication, Dec. 30, 1955.

CRANIAL PLANE

According to Transographics, however, the important reason for establishing this plane is in order to be able to repeat natural deviations of functional jaw movements from off the sagittal plane on the articulator. Without this plane, off-sagittal function on the articulator has no useful relation to off-sagittal function in the mouth. The cranial planes or axis orbital planes of Wadsworth, McCollum, and Simon run from and to some specific anatomic landmark and are repeatedly taken from these same positions. In Transographics, it is not necessary to return to the same anatomic landmark (Fig. 10). The claim is made that it is only important that the point established in each operation be repeated on the machine. The cranial plane is defined as "the relationship of any convenient cranial reference point to the hinge axes."[23]

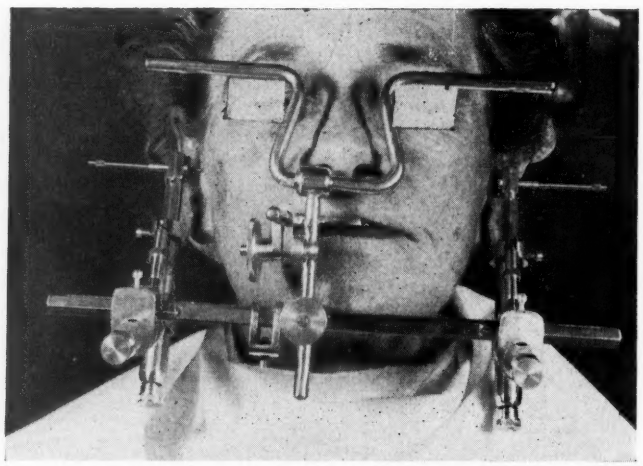

Fig. 10.—The cranial plane is established by the head relator.

The establishment of a cranial plane makes possible the projection of the rotational centers of each condyle. (These points are located in the skin and are regarded as the posterior apexes to a third anterior apex.) A relationship is established between the entire cranium, the maxillae, and the transverse hinge axes which is carried over to the articulator by means of a wax interocclusal record on a bite fork that is attached to a cranial plane indicator called a head relator (Fig. 11).[13] With these relationships established, the vertical dimension may be changed on the machine without interfering with mouth function.

A hinge "bite" is defined as "the relationship of properly oriented bite-blocks or wax bites to the hinge-axis."[13] A hinge relation is defined as "the relationship of any convenient cranial reference point to the hinge-axis."[13] On the Transograph, this is done by having the hinge-bow and cranial plane indicator (head relator) locked to a hinge interocclusal record, and adjusting these on the machine so that, on the machine, the measurements will agree with the measurements in the head. The wax interocclusal records can now be removed, and the relationship

of the opposing bases or teeth will be one of hinge occlusion which is defined as "the relationship of naturally occluded teeth to the hinge relation."[13]

LATERAL JAW MOVEMENTS VERSUS NATURAL JAW FUNCTION

Lateral jaw movements versus natural jaw function is another controversial subject. Jankelson,[25] Kurth,[26-28] Boswell,[29] Hildebrand,[30] Payne,[31] Shanahan,[32] and others have done research along these lines. This concept not only agrees with them but even goes further.[10, 24]

When a person chews naturally, he does not move his jaw horizontally from side to side and protrusively forward. He opens his mouth liberally, moves his jaw to one side, grasps the food, and then closes his mouth during which time, in the closing stroke, the mandible travels upward, inward, and forward to make contact with the opposing teeth. The cusps rarely, if ever, engage in lateral movement on the horizontal plane. As the cusps of the natural teeth close from the

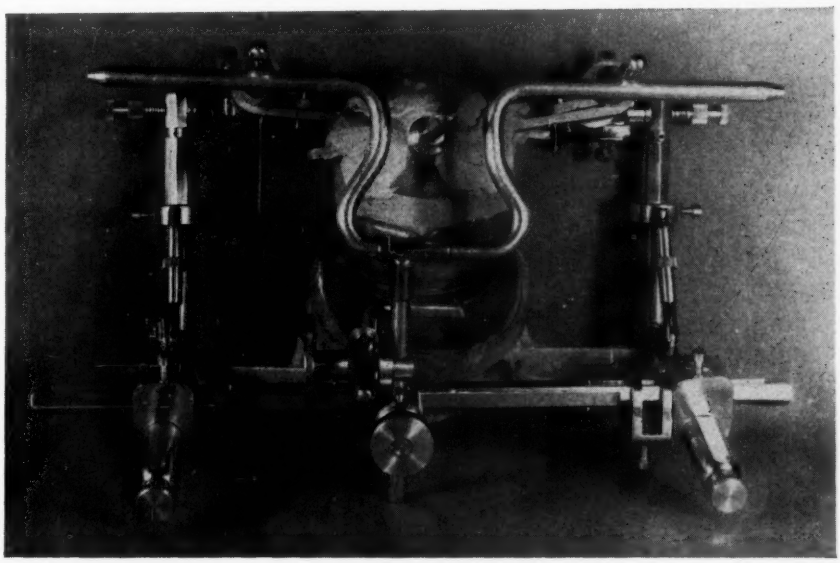

Fig. 11.—The relationship between the cranium, the maxillae, and the transverse hinge axes is carried over to the articulator.

open position, they assume an angle of closure that enables them to clear the opposing cusps until they attain complete closure. Ask a person to close his teeth with or without food, and you will observe that even in quick closure, there is never a cusp interference in any normally good occlusion, in spite of the fact that in most persons with excellent teeth and bone structure, there is rarely a simultaneous contact in work and balance, which is the stated aim of all of our artificially fabricated occlusions.

The angle of closure is all-important in order that the cusps avoid clashing while the functional closing stroke is being used. There is a certain angle within which the jaw moves in final closure in the transverse plane. This angle bounds

functional jaw movements; therefore, it must be incorporated in the articulator. It is within the patient's natural envelope of jaw motion. According to Transographics, the functional jaw movement pattern differs considerably from the envelope of motion that limits the range of artificial radial lateral movements. The angle of final closure is somewhere over 50 degrees and under 70 degrees off the cranial plane.[23] This becomes of extreme importance in the final short range of interdentation. If that angle is recorded on the articulator, any of the closure strokes used by the patient may be reproduced with accuracy. In the calculation of the angle of final closure, the works of Boswell,[33] Kurth,[26] and Hildebrand[30] were used for comparison, in addition to the experimentation of the inventors. The flattest angle was around 50 degrees off the cranial plane. The steepest angle was under 70 degrees. To reproduce the flattest angles, a jaw-movement guide with adjustable cams is attached to the Transograph (Fig. 12). These are set slightly above the flattest closure angle revealed by the patient's pantographic records. In actual practice, this turns out to be 55 degrees. The cams are set initially at 55 degrees.*[16, 23]

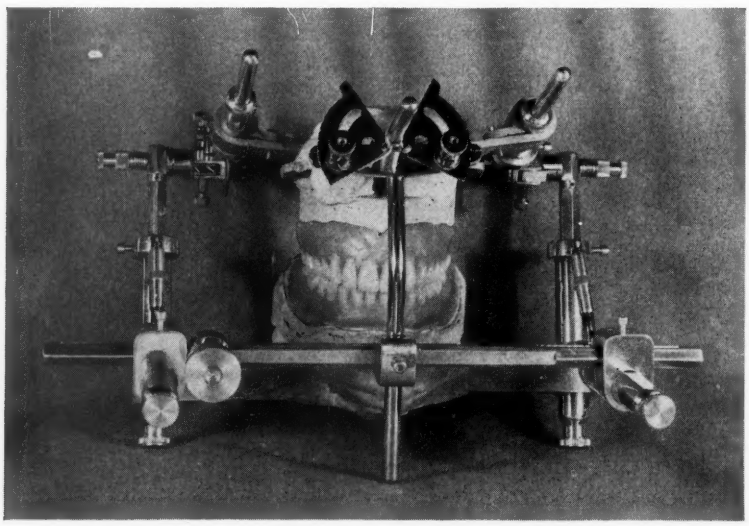

Fig. 12.—The jaw movement guide with the cams set at 55 degrees off the cranial plane is attached to the instrument.

Teeth articulated to function with the conventional articulators are prepared on the wrong surfaces, because when the mandible moves in a medial-lateral direction while gliding on a horizontal plane, the movement of the occlusal surfaces is retrusive, whereas, while closing in the medial functional stroke, the natural occlusal movement is protrusive. The claim is made that the Transograph is the only articulator that is capable of reproducing the natural functional movements.[10, 14]

OCCLUSAL CURVES

Occlusal curves in an orthodox occlusion are supposed to be generated by the condyle paths. According to the proponents of Transographics, these curves

*Harry L. Page: Personal communication, April 16, 1956.

are generated when horizontal lateral movements, which are artificially induced, are made. These curves can be made with contacting occlusion rims in edentulous cases. However, when we chew naturally, there is no tooth contact until the final closure is made or until the swallowing act occurs, which takes place in final closure. Therefore, these occlusal curves generated by artificial lateral movements are artificial curves. The natural curve anteroposteriorly must be the product of radii from the hinge axis to each tooth, modified by the mandibular or gonial

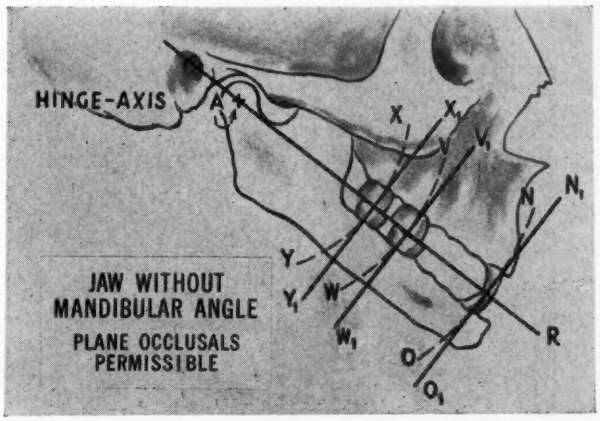

Fig. 13.—A jaw without a mandibular angle. (From Harry L. Page, Dental Digest, Jan., 1952, p. 20.)

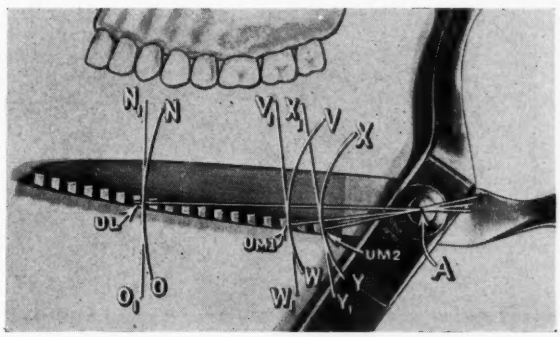

Fig. 14.—The influence of a mandibular angle. An occlusal curve is unavoidable. (From Harry L. Page, Dental Digest, Jan., 1952, p. 20.)

angle. *"The occlusal curve is a composite of opposed occlusal surface curvatures in the sagittal, frontal, and horizontal planes"*[17] and not a by-product of condyle paths. If the ramus and mandible were a straight line from the condylar hinge axis to the incisal edge of the anterior teeth, and the mandible simply opened and closed under these conditions, we could have plane occlusion and plane occlusal surfaces (Fig. 13). The human jaw does not happen to be built that way. The mandibular angle together with the hinge axis results in the anteroposterior occlusal curve common to human occlusions (Fig. 14).[17]

Fig. 15.—Functional "bite plates" in the patient's mouth. These are chewed-in protrusively and right and left laterally, with the upper and lower occlusal surfaces of the records contacting. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

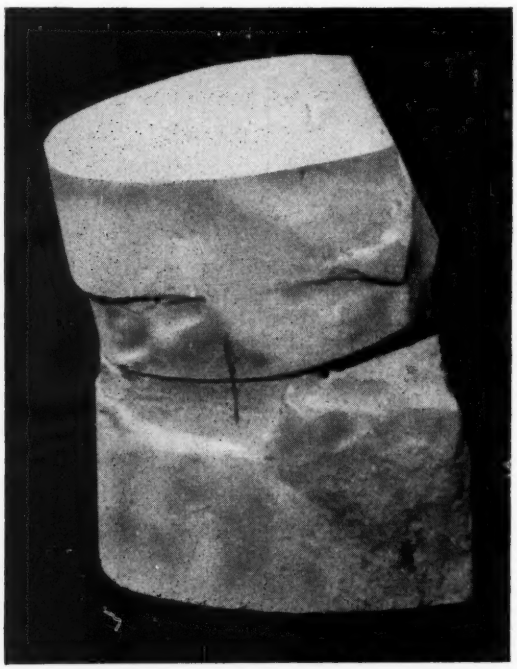

Fig. 16.—When the functional "chew-in" records are poured, the occlusal curve shows a space posteriorly. Transographics explains why this space is present. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

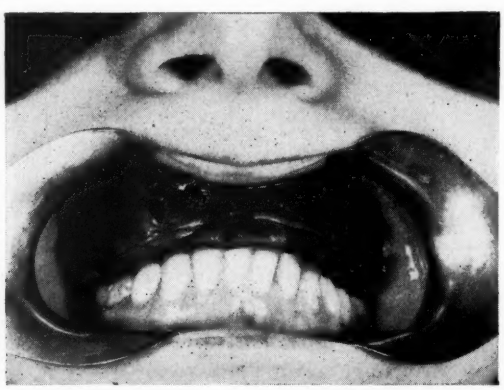

Fig. 17.—The patient "chews-in" occlusal paths on a modeling compound rim. (From Schweitzer, Restorative Dentistry, The C. V. Mosby Co., 1947.)

DIFFERENCE IN ENVELOPES OF MOTION

Kurth stressed the fact that natural jaw function differed completely from the movements controlled by the stylus and metal plate so often used even today in obtaining records with which to adjust articulators.[28] The Transographic concept seems to agree with him and briefly describes it as follows:

When a (Gothic arch) needle point tracing is made with a stylus and a metal plate, the apex of the tracing is said to indicate the most retruded position from which lateral movements can be made at a given vertical height. However, when a patient opens at the start of function, the body of the mandible drops further back, instantly, along the opening arc. Therefore, in all functional movements, the occlusal surfaces of the lower teeth are behind the artificially induced horizontal lateral movements. The base lines of the needle point tracing represent the forward terminal of all functional movements. Therefore, these two types of movements are entirely different. Lateral motion may be indulged in, but it is not used in function. The envelope of motion which is drawn on a single plane does not represent function because it is entirely distal to, i.e. outside of, function.[10, 14, 16]

"CHEW-IN" TECHNIQUE AND ITS RESULTS

In the "chew-in" technique, as described by Christensen in 1902, and by Paterson[31–36] and Meyer,[37, 38] interocclusal waxes were used with plaster or carborundum paste in a special trough built in the occlusion rims, and functional paths were generated. I have often wondered why there was always a space between the posterior ends of the generated paths! I remember the advice to take the upper second molars out of occlusion in edentulous cases. The "chew-in" is started with the vertical dimension overraised, and, as the "chew-in" takes place, the operation is halted at the correct vertical dimension (Figs. 15-17). Sometimes a central bearing instrument is used to control the grinding, or three simultaneous central bearing instruments are built into the occlusion rims.[39, 40] This concept claims that these spaces result from voluntary radial lateral motions, both in dentulous and edentulous cases and, therefore, these horizontal lateral motions are ruinous to articulation.[16] Experiments were performed[24] in which the upper and lower denture bases were made with wax occlusion rims. "They have been made by taking impressions and pouring stone models of the originals after the latter had been fitted and apposed properly in the patient's mouth."[24] The Transograph was used as the articulator, and it reproduced the patient's static and kinematic head relationships. When lateral movements were used, the nonworking side collided violently. Just as soon as the return stroke was used, the occlusion rims were released. If the occlusion rims were set to contact each other or were slightly separated, the posterior portions of the rims are ground away in radial lateral strokes (Fig. 18).

Milling teeth in the mouth is claimed to cause the same results. All the milled teeth have surfaces which in no way resemble natural teeth. It makes little difference whether the so-called envelope of motion is developed by a single tracing device or by the elaborate technique used in Gnathology. The envelopes of motion recorded are distal to, and not the same as, those developed when using a natural

functional masticatory stroke. It has been said repeatedly that grinding teeth in the mouth is ruinous to correct occlusion—that teeth do not grind themselves into balanced occlusion, but out of it. There is little difference whether the artificial voluntary lateral movements which are so often used in bruxomatic movements do their grinding with or without tracing devices—the results are the same. An envelope of motion is used which is entirely different from that developed in the natural jaw synergy.[16]

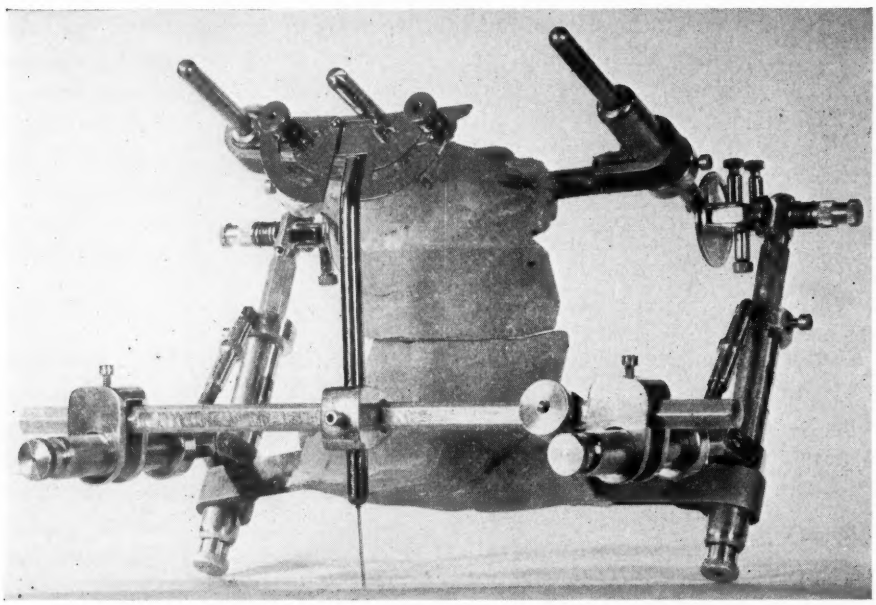

Fig. 18.—Abrasion resulting from right lateral strokes. The left posterior (nonworking) rims were out of contact in simple closure. (From Harry L. Page, Dental Digest, May, 1954, p. 204.)

CONDYLE PATHS HAVE NO VALUE

This concept is by no means the first to discredit the importance of condyle paths in establishing balanced occlusion. Boswell[29] stated: " . . . a record of condyle path movement is not one of condylar guidance, but is one of response to limitation, and can have no value when the mandible moves to any other position." Kurth,[27] Craddock,[41] and others could be quoted with reference to the fallacy of condylar guidance and balanced occlusions, but the Transographic concept emphasizes the lack of importance of condyle paths.[10–12] The condyles do not move in inflexible grooves. The path which is always recorded is that of the nonworking condyle. In making lateral interocclusal records of right mandibular movement, it is the left condylar path which is set and vice versa when the right condylar path is set. This nonworking condyle glides in all three planes upon the posterior slope of the articular eminence and also upon the inner curbing of

the bone of the fossa.[15] These slopes have different angulations, but the nonworking condyle rotates and translates freely in all planes just as a perfect universal joint. It acts to protect the mechanism against sudden force, but in no way does it control jaw function. The working condyle is also a universal joint but not to the same degree. It rotates and translates in three dimensions, but when it finally reaches its fulcral position on the posterior slope of the articular eminence, it then becomes the fulcrum for jaw power. It is anchored there by muscles, the tension of which is partly relieved by the temporomandibular ligament. The nonworking condyle "idles along," rotating and translating until it, too, finally reaches its fulcral position on the posterior slope of the articular eminence. Both condyles are then in their hinge positions. Both then rotate in these fixed positions. There is no longer translation except for the Bennett movement.[14]

Kurth,[28] Craddock,[41] and Jankelson[25] stressed the lack of value of the condyle paths and of balanced cusp relationship as a part of functional jaw synergy. The dental schools teach that the ideal occlusion is one in which there is simultaneous cusp contact in lateral and protrusive movements, anteriorly, laterally, and posteriorly. Clinically, such occlusions are very rare. To deny such control factors as the condyle paths is still heresy.

Some among those who use standard concepts, and at the same time agree that condyle paths are unimportant and lateral motions are artificial, offer a new version. This group claims that since most people idly grind their teeth, smooth lateral paths must be provided to permit these pathologic movements to continue. Transographics states: "Essentially, this new rationalization agrees that laterals are worthless functionally but elevates bruxism and bruxomania to the status of virtues where once they were injurious and factors to be eliminated by every possible means."[10]

There are adjustable condyle slots on the Transograph. These were placed there for commercial reasons. The inventors felt that since they do no harm, they might as well be left adjustable for those who are still not convinced that condyle paths have no value.* They can be adjusted to any angle and, if the jaw movement or chewing angle guide has its cams lowered, the Transograph may be used as any other articulator to utilize voluntary radial lateral motions. The inventors, however, disapprove of the articulator being used in that manner.†

MANDIBULAR CLOSURE

The mandibular body, in the early phases of closure during the period in which the condyles are translating, has its axes in the mandibular angle. The masseter and the internal pterygoid muscles form its sling (Figs. 19 and 20). Transographics claims that these fibers, being directed inward and forward, tend to arc the body of the mandible upward and slightly forward, while the condyles are moving upward and backward along the anterior fossal slope, being aided in this movement by the posterior fibers of the temporal muscles. When the working condyle reaches the hinge position, the axis changes to within the con-

*Harry L. Page: Personal communication, Dec. 30, 1955.
†Harry L. Page: Personal communication, Feb. 11, 1956.

dyle, and the condyle can only rotate while the closing musculature applies the power.[14] It is argued that the cusps never completely interdentate until total closure, or until deglutition takes place.[25]

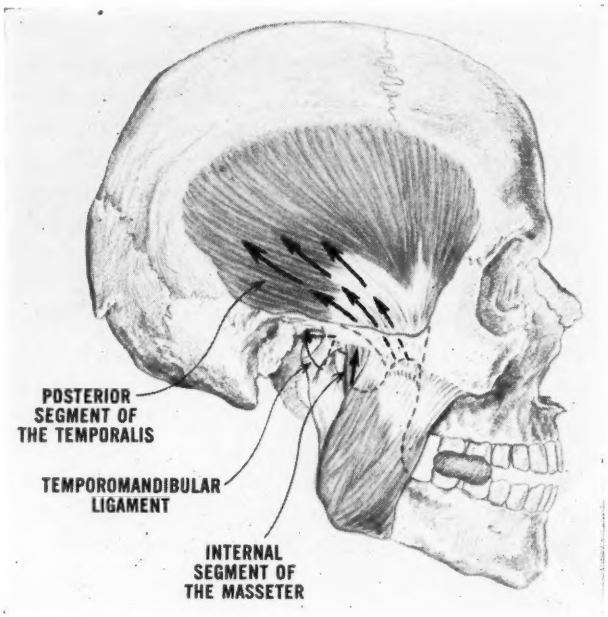

Fig. 19.—The working condyle is anchored in hinge position during the final power closure. (From Harry L. Page, Dental Digest, Feb., 1954, p. 56.)

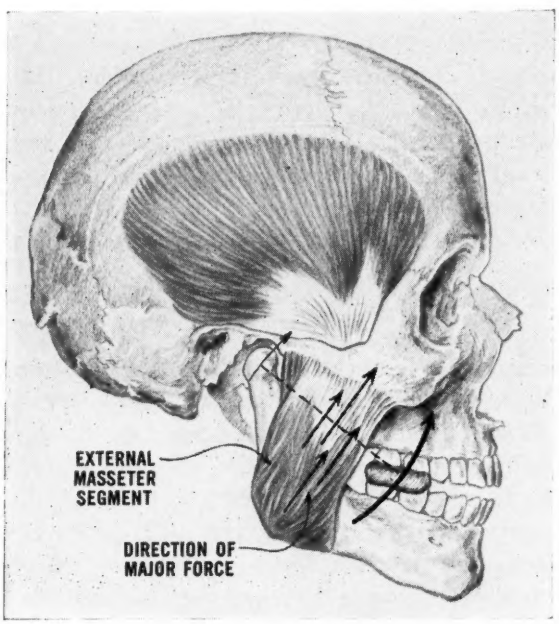

Fig. 20.—The fossal slope prevents a forward arcing of the condyle during function. (From Harry L. Page, Dental Digest, Feb., 1954, p. 57.)

Cusp contact during the chewing of food is highly controversial, but an excellent case has been built up to support the theory of no contact until final closure.[25, 32, 42–46] If this is so, why is it so necessary to obtain simultaneous "balancing" contact? It follows that if cusp contact cannot be achieved in order to initiate the guiding of the tooth surfaces of the opposing arches over each other, then a supposedly balanced glide from the lateral working occlusion in the horizontal plane medially to centric position in normal natural dentition is a myth[24] and impossible to attain. Lateral movement of natural teeth in mouths in which the teeth are in normally good condition will generally result in contact only in the extreme molar areas on the nonworking side. The anterior teeth will contact in protrusive movements and leave the posterior teeth apart.[24]

A PROTRUSIVE WAX INTEROCCLUSAL RECORD USED TO SET THE CONDYLE PATHS

Transographics states that a protrusive wax interocclusal record, which is a conventional method of setting a condyle path, is difficult to duplicate. No two recordings could be the same except by accident. Since none is the same, the only safe conclusion must be that none is correct.[10] Craddock proved this.[47] This was also substantiated by Beck and Morrison. "In the condylar articulator, the setting of the condylar indications by a protrusive interocclusal record is influenced by the magnitude of the protrusive movement, the path and deviation from plane motion of the incisal guide point, the inclination of the incisal guide, the position of the incisal guide, the amount of opening or closing of the occlusal relationship, the inclination of the interocclusal record, the relationship of the plane of the condylar slot with the sagittal plane, and the position of the interocclusal record."[48] The results are only the effort of a universal joint in adapting itself. This record is not accurate, nor is the straight protrusive record correct in reproducing lateral protrusive movements as is common procedure. With the fossal curvatures of different shapes medially and protrusively, how can one record determine both angulations?[49]

FALLACY OF THE USE OF A CENTRAL BEARING PIN

When a central bearing pin is used, some of the very muscles which are employed to perform the natural chewing stroke are immediately eliminated. All of the closing muscles, namely, the masseter, the anterior fibers of the temporal, and the closing fibers of the internal pterygoid are taken out of the functional closing synergy. The muscles that operate are the internal pterygoid pulling medially, and the nonworking temporal fibers pulling posteriorly. The jaw cannot open or close since its movements are confined to a metal plate by the stylus and by the voluntary action of the patient. The jaw moves medially and retrusively in the horizontal plane only. The usual procedure employs radial lateral movements in making jaw records. Here, Transographics, contends the situation is even worse, only the external pterygoid muscle on the nonworking side and the posterior fibers of the working temporal muscle are active. All of these are nonfunctional movements. What effect, under conditions such as these, are condyle paths and Bennett movements recorded by the most accurate articulators? They

may be repeated with accuracy, but they do not prove function. They are solely controlled by the pin on the incisal guide plate.[10]

Experiments have been performed to prove that the occlusal surfaces disrupt the paths taken by the translating condyles and that the condyles conform to occlusal interferences.[10]

DISCUSSION

Many are not yet convinced that all voluntary lateral jaw movements on the horizontal plane are nonfunctional and pathologic. There are those who are inclined to feel that with certain types of food these horizontal lateral movements may be normal for some people.

The theory of Transographics provides for the use of steep cusps (35, 40, and 45 degrees), which, in turn, discourage the patient from making radial lateral motions which are considered bruxomatic and pathologic. Where the periodontal structures are weak, and where there has been considerable loss of the supporting bone, the theory of steep cusps does not seem to be logical. Many would prefer to use a flatter than normal chewing angle with flatter cusps. Although the Transograph will accept any chewing angle, the theory of Transographics does not accept it. In their opinion "it is poor practice."*

I feel that some of the settings of the Transograph are arbitrary. They admit that the distance between the condyles is arbitrary, but the claim is made that it is close. On the more recent models, they have made provision to measure this distance more accurately. It must be admitted, however, that standard instruments have an even greater inaccuracy (Fig. 9).

The jaw movement guide is set at an average of 55 degrees off the cranial plane. If the natural chewing stroke is somewhere between 50 degrees and 70 degrees off the cranial plane, the 55 degree setting is arbitrary. This chewing angle controls the cusp angles at final closure so that an error may be introduced here, although it must be admitted that it is a negative error. Only the transverse hinge axes were actually located. The vertical and sagittal axes which control motion on the horizontal and transverse planes were only pantographed from the experiments formerly referred to of Boswell, Kurth, Hildebrand, and the inventors. More substantial proof of these experiments, including those of the author, should be presented.

Another point which needs further clarification is the total separation of the two envelopes of motion, namely, that produced by so-called nonfunctional radial lateral movements and that produced by the so-called natural jaw synergy or true function. Unless all function occurs on the hinge axis, there would be a "crossing over," at various levels, of these two envelopes of motion when looking down from above the head on the horizontal plane, or when viewing the head from the side on the sagittal plane (Fig. 21). Inside the envelope of motion is a pattern of function. If this pattern of function were to be drawn diagrammatically in the sagittal and horizontal planes, its position would be somewhere forward

*Harry L. Page: Personal communication, Feb. 11, 1956.

of the hinge-axis line. The line representing the hinge axis position would be its posterior boundary. At final interdentation, however, the posterior border or hinge position would be reached.

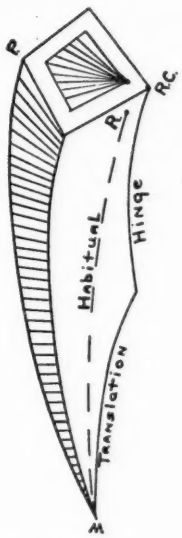

Fig. 21.—The pattern of jaw function within the envelope of motion. Habitual motion does not take place on the hinge axis but anterior to it. When the mandible opens from the retruded contact position (*RC*) it can be made to move along the arc representing the hinge axis, and then the arc representing translation. Habitual eccentric movements, however, take place slightly forward at about rest position (*R*). Therefore, there will be an overlapping of the two envelopes of motion during mastication. No movements will be found to the right of the hinge translation line; all movement takes place to the left of it. (*M*) indicates maximal opening. (Modified from H. L. Beyron: J.A.D.A. 48:648-656, 1954; and from Ulf Posselt, Odont. Scan. 10:94-95, Sup. 10, 1952.)

When in operation, the vertical axes act as the pivoting mechanism for either the right or left sides, respectively. It seems, therefore, that these axes are arbitrarily in direction and rigid in their control of movement. It is not possible to locate accurately the vertical and sagittal axes. These were pantographed from the patient's chewing angle. Relative to my questions concerning these points, the inventor admits that the location of the vertical axes is not entirely accurate. Then he states, "In functional motion, the slide and slider assembly with the spring on the transverse axes operates first to create and then to accept a torque that sways the upright arm or slides the transverse axis somewhat. This, in conjunction with the functional jaw pattern inside the envelope of motion created by the jaw movement guide cams, shifts the vertical, sagittal, and transverse axal centers into composite positions equivalent to the same positions they hold in the head while moving the jaw along the same path. Under these conditions, it is not important whether the articulator hinge axis does or does not intersect the transverse hinge axis . . . . I have computed the amount of allowable error and have seen to it that the tolerances for avoiding cuspal interference were given a generous safety factor."*

The transverse axal centers of the Transograph are always parallel to each other on the instrument (see any photograph of the instrument). It is true that

*Harry L. Page: Personal communication, April 19, 1956.

one of the right or left axal centers may be higher or lower than the other, or forward or backward of the other, but they are still always parallel. This would hardly be possible in the skull where one axal center may converge toward the other if it were projected as a transverse axis. To this question of the parallelism of the transverse axal centers, the inventor has this to say, "All Transograph parts except mandibular angle are perpendicular or parallel to each other in order to capture head asymmetries accurately." "An axis is invariably perpendicular to the plane of rotation. A wheel never rotates at any but a right angle to its axle."*

Transographics admits the location of definite transverse axal centers and marks their external location by points on the skin. Some operators claim to record areas, not points.[7,19,49,50] Therefore, the accurate location of the projection of these centers on the skin is questionable. Transographics claims that this tends to substantiate the claim that the rotational controls are asymmetrical axal centers, and not point centers. Therefore, when the head records are transferred to the instrument, it twists the same way that the jaw twists when the styli give the appearance of locating areas on the skin.

An important objective in this theory is that the so-called hinge "bite" (interocclusal record) be made with the mandible in its most retruded position. Adherents of this theory use manual pressure in obtaining these records. In patients with temporomandibular dysfunction which is due to posterior condylar displacement, this method of registration may serve only to aggravate an already pathologic condition. Therefore, the theories of Transographics would not apply to these treatment cases. The inventor agrees with this.

It is difficult for many men to concede that condyle paths have no value and that the nonworking condyle "idles along" until it reaches its hinge position. According to this theory, the nonworking condyle acts as a universal joint and conforms to any and all occlusal interference. They maintain that only the working condyle controls jaw movement arcs within the terminal functional orbit. While the experiments of Kurth,[51] in which he claimed to demonstrate the wide variance of condylar angulation in the sagittal plane when different surfaces were used on intraoral tracers, seemed to agree with Transographic concepts, those of Downs[52] disagreed with them. Downs claims that his investigations have shown that if the point of the transverse hinge axis is projected onto the face, and if the condyle path is started at this point, then the central bearing plate in the mouth may be changed from convex to concave to flat with no effect upon the condyle path.

In operations where the disk has been removed, it has been shown often that the condyle path is immediately changed, and the occlusion is interfered with as a result. They concede that this is a change in tooth interdentation but maintain that it is due to a new hinge position of the working condyle as a result of the removal of the meniscus and its external pterygoid attachment.† While it is true that tooth structure is hard and unyielding, and while the condyles are loosely encapsulated and exhibit much more flexibility, still experience has shown that tooth

*Harry L. Page: Personal communication, April 27, 1956.
†Harry L. Page: Personal communication, March 14, 1957.

cusps, masticatory muscles, and condyle paths all exhibit some degree of control over each other which will vary with the individual. "If the temporomandibular joint enjoyed the latitude of free movement and adaptability which some individuals claim it is capable of, then there would be no such pathologic entity as a temporomandibular joint disturbance directly traceable to a malocclusion, and very few teeth would be lost because of traumatic occlusion."[53]

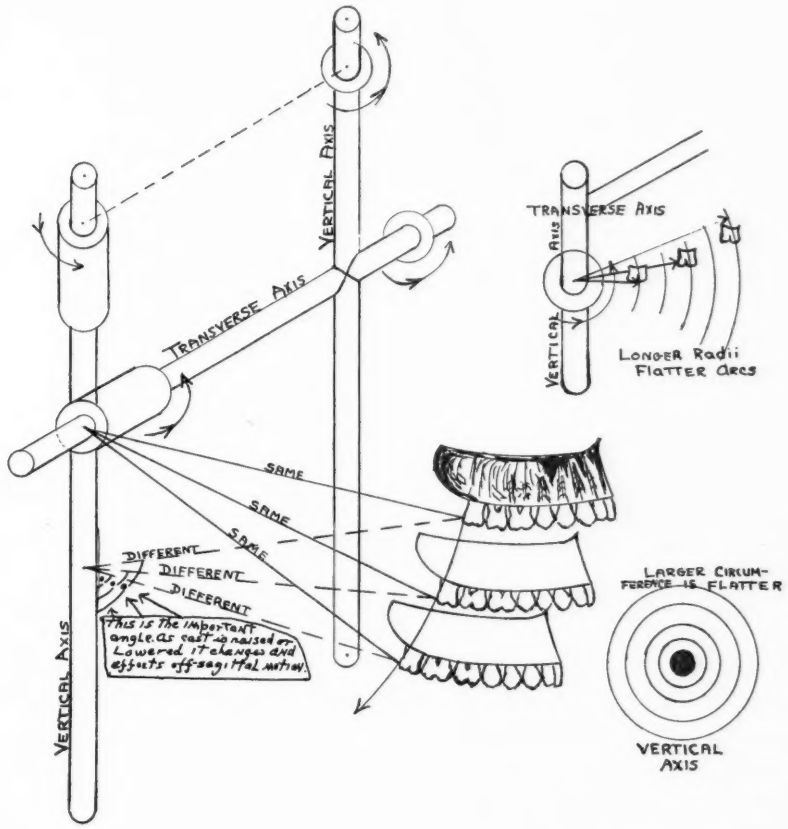

Fig. 22.—The cranial plane necessary to record equivalents of the off-sagittal plane movements made by the subject in function.

The inventors state that one of the most convincing demonstrations of the entire theory is the ability of their instrument to accept various thicknesses of hinge "bites." They claim that this is difficult, if not impossible, with the conventional articulators. During the past year, I have conducted three experiments to test the greater accuracy claimed for the Transograph over conventional articulators. All three competitive instruments which I used seemed to be equally accurate so that, in honesty, I cannot discredit the conventional articulator, nor can I discredit the claims of the inventors as to the accuracy of their machine. My experiments were not conclusive enough to me to prove anything.

A clever arrangement of the Transograph is its ability to check the correctness of different wax interocclusal records. The arrangement of the condylar slide plate and slider is the most accurate method of checking interocclusal records that I have ever seen on any articulator.

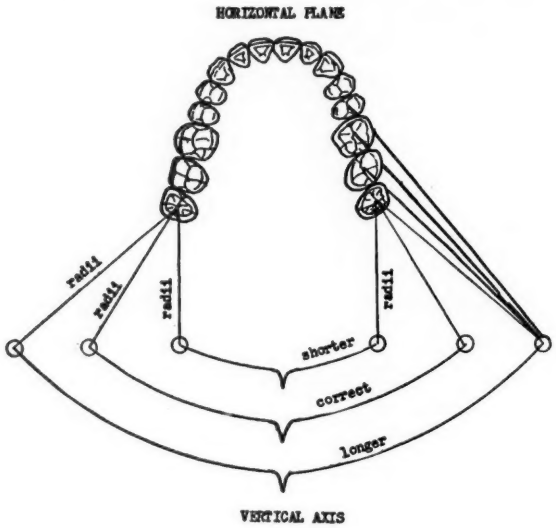

Fig. 23.—The importance of using the correct intercondylar distance. If vertical axes are not the same distance apart on the articulator as they are in the head, the radii will be different as they relate to each tooth. They will be shorter, if closer, and longer, if further apart. This will also affect the cusps of the teeth in off-sagittal motion on the horizontal plane. Therefore, the intercondylar distance should be the same on the articulator as in the head.

The concept of the cranial plane is the most difficult one to understand. Its purpose is to establish the correct relationships of axes to occlusal surfaces and to the cranium so that off-sagittal plane movements on the horizontal and transverse planes, regardless of how small they may be as compared with sagittal movements, are equivalent to off-sagittal plane movements made by the subject in function. My understanding of their concept is as follows: The transverse axes record rotational movements in the sagittal plane so that the occlusal surfaces have the same radii with reference to the transverse hinge axes as they have in the subject. If it were only to relate the occlusal surfaces in that plane, you could safely divide the distance between the upper and lower articulator frames as is the usual procedure in the Hanau Model H or the Kinescope (Fig. 22). In fact, various teeth. But horizontal and transverse plane movements, as small as they desired without changing the lengths of the radii from the transverse axis to the various teeth. But, horizontal and transverse plane movements, as small as they may be in the natural jaw synergy, are controlled by vertical and sagittal axes (Figs. 23 and 24). These or their equivalents must be recorded and related to the occlusal surfaces in the articulator. This is done in Transographs by the use of a cranial plane. In Gnathology, it is done by the use of the axis orbital plane.

The important angle to consider is the one made by the upper occlusal plane and the vertical axes. Then, horizontal or transverse movements of the occlusal surfaces will have the same radii at all times as they had in the subject's head, and interdentating cusps, whether in edentulous patients or in dentulous patients, will move along the proper arcs when they are returned to the mouth.

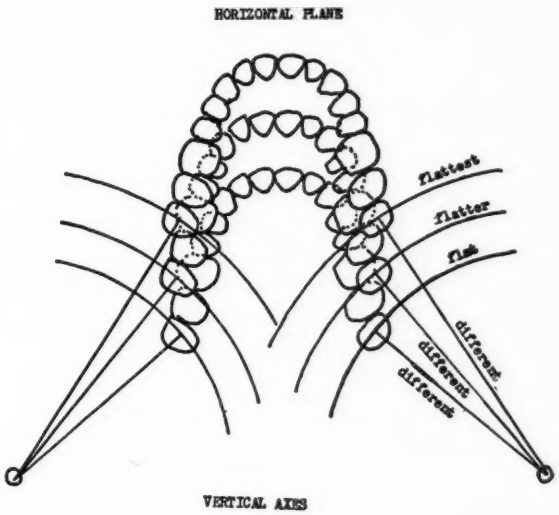

Fig. 24.—The importance of cranial plane and the effects of raising the casts on the articulator. As the cast is raised on the articulator, the teeth are moved further forward. The radii from the vertical axes to each tooth on this horizontal plane get longer as the cast is mounted higher on the articulator. This makes flatter circumferences of the arcs of the concentric circles, and, therefore, will affect the cusp form in off-sagittal motion on this horizontal plane.

CONCLUSION

An attempt has been made to present the theory and practice of Transographics. Although it claims very few original ideas, its concept and instrument represent something new and intriguing. It is entirely different from our traditional ideas. There is a big difference between the Transograph and conventional articulators. One must open his mind to receive these concepts without being prejudiced by personalities. Our profession has never had any fear in being exposed to new theories. As time goes on, it will be able to evaluate this one.

In this article, I have made extensive use of material from the writings of Mr. Harry L. Page, one of the collaborators on the theory of Transographics, and the inventor of the Transograph. The other collaborator is Dr. Reuben N. Albinson. I have tried to condense the material while putting most of it in my own words. I wish to acknowledge the help I have received from the former of the two collaborators. Without it, this concept, which involves mathematics and engineering, would have been much more difficult for me to present. On the other hand, no restrictions were imposed upon me should my experiences prove to be contrary to those stated to have been found by him and his associates. It was agreed that I was free to form my own opinions in a personal communication dated Sept. 25, 1956.

REFERENCES

1. Page, Harry L.: Centric and Hinge-Axis, D. Digest **57**:115-117, 1951.
2. Idem: The Bennett Movement, D. Digest **57**:412-414, 1951.
3. The American College Dictionary, New York, 1953, Random House.
4. McCollum, Beverly B.: A Research Report. Part I. Fundamentals Involved in Prescribing Restorative Dental Remedies. Part II. Articulation of Human Teeth, D. Items Interest **61**:522-535, 641-648, 724-736, 852-863, 942-950, 1939.
5. Stuart, Charles E.: Articulation of Human Teeth, D. Items Interest **61**:1029-1037, 1147-1154, 1939; **62**:8-17, 106-112, 1940.
6. Page, Harry L.: Centric and Plane Occlusion Mean Flat Teeth, D. Digest **58**:210-212, 1952.
7. Schuyler, Clyde H.: Factors of Occlusion Applicable to Restorative Dentistry, J. Pros. Den. **3**:772-782, 1953.
8. Page, Harry L.: Lexicography, Hinge Opening, Hinge Closing, and Centric, D. Digest **61**:17-23, 1955.
9. Idem: The Bennett Movement, D. Digest **57**:412-414, 1951.
10. Idem: Occlusal Movements and Obstructions: The Bennett Movement—Part I, D. Digest **61**:344-349, 1955.
11. Idem: Occlusal Movements and Obstructions: The Bennett Movement—Part II, D. Digest **61**:395-398, 1955.
12. Idem: Temporomandibular Joint Physiology and Jaw Synergy, D. Digest **60**:54-59, 1954.
13. Idem: Maxillomandibular Terminal Relationships, D. Digest **57**:490-493, 1951.
14. Idem: The Hinge-Bow, D. Digest **58**:534-537, 1952.
15. Hjortsjö, C. H.: An Apparatus Illustrating the Mechanism of the Temporomandibular Joint, Odont. Revy. **4**:93-106, 1953.
16. Page, Harry L.: Natural Articulation Movements, D. Digest, **59**:202-206, 1953.
17. Idem: The Occlusal Curve, D. Digest, **58**:19-21, 1952.
18. Hjortsjö, C. H.: Studies of the Mechanics of the Temporomandibular Joint, Hakan-Ohlssons Boktryckeri, 1955, pp. 8, 10.
19. Page, Harry L.: Transographics and the Transograph, Part I, D. Digest **62**:162-167, 1956.
20. Hjortsjö, C. H., Persson, P. I., and Sonesson, B.: Studies on the Shape of the Articular Eminence With Its Relation to the Mechanism in the Temporomandibular Joint, Odont. Revy. **4**:187-202, 1953.
21. Fick, F.: Handbuck der Anatomie und Mechanik der Gelenke, Jena, 1911.
22. Granger, E. R.: Centric Relation, J. Pros. Den. **2**:160-171, 1952.
23. Page, Harry L.: The Cranial Plane, D. Digest **61**:152-157, 1955.
24. Idem: An Appraisal of Balance, D. Digest **60**:200-204, 1954.
25. Jankelson, B., Hoffman, G. M., and Hendron, Jr., J. A.: The Physiology of the Stomatognathic System, J.A.D.A. **46**:375-386, 1953.
26. Kurth, LeRoy E.: Problems Related to Occlusion With Complete Upper and Partial Lower Dentures, J.A.D.A. **43**:691, 1951.
27. Idem: The Physiology of Mandibular Movement Related to Prosthodontia. New York D. J. **15**:323, 1949.
28. Idem: Mandibular Movements in Mastication, J.A.D.A. **29**:1769-1790, 1942.
29. Boswell, J. V.: Practical Occlusion in Relation to Complete Dentures, J. Pros. Den. **1**:307-321, 1951.
30. Hildebrand, G. Y.: Studies in the Masticatory Movements of the Human Lower Jaw, Scand. Arch. f. Physio. Supp. 61, 1931.
31. Payne, S. Howard: A Comparative Study of Posterior Occlusion, J. Pros. Den. **2**:661, 1952.
32. Shanahan, T. E. J.: Dental Physiology for Dentures, J. Pros. Den. **2**:3-11, 1952.
33. Boswell, J. V.: Practical Occlusion in Relation to Complete Dentures, J. Pros. Den. **1**:307, 1951.
34. Paterson, A. H.: Construction of Artificial Dentures, D. Cosmos **65**:679-689, 1923.
35. Idem: Establishing the Prosthetic Curves of Occlusion on the Bite Blocks in Full Denture Construction, J.A.D.A. **14**:1197-1203, 1927.
36. Idem: Influences of Mandibular Movements on Balanced Occlusion, J.A.D.A. **15**:1118-1120, 1928.
37. Meyer, F. S.: Balanced and Functional Occlusion in Relation to Denture Work, J.A.D.A. **22**:1156-1164, 1935.
38. Idem: A New, Simple, and Accurate Technic for Obtaining Balanced and Functional Occlusion, J.A.D.A. **21**:195-203, 1934.
39. Brenner, George P.: A Functional Denture Technic, J.A.D.A. **27**:1873-1883, 1940.
40. Shanahan, T. E. J.: Mandibulographed Dentures, New York J. Den. **12**:303, 1942.
41. Craddock, F. W.: The Accuracy and Practical Value of Records of Condyle Path Inclination, J.A.D.A. **38**:697, 1949.

42. Yurkstas, A. A.: A Study of Tooth Contact During Mastication With Artificial Teeth, J. D. Res. **29**:133-136, 1950.
43. Hardy, I. R.: Technique for the Use of Non-Anatomic Acrylic Posterior Teeth, D. Digest **48**:562-566, 1942.
44. Boos, R. H.: Occlusion From Rest Position, J. Pros. Den. **2**:577, 1952.
45. Hughes, F. C.: Elusive Objectives in Complete Denture Prosthesis, J. Pros. Den. **1**:543-550, 1951.
46. Idem: Form and Function in Teeth and a Rational Unifying Principle Applied to Interpretation, Internat. J. Orthodont. **10**:703, 1924.
47. Craddock, F. W.: The Accuracy and Practical Value of Records of Condyle Path Inclination, J.A.D.A. **38**:697-710, 1949.
48. Beck, H. O., and Morrison, W. E.: Investigation of an Arcon Articulator, J. Pros. Den. **6**:359-372, 1956.
49. Borgh, Olle, and Posselt, Ulf: Hinge Axis Registration: Experiments on the Articulator, Odont. Revy. **7**:214-220, 1956.
50. Kurth, L. E., and Feinstein, I. K.: The Hinge Axis of the Mandible, J. Pros. Den. **1**:327-332, 1951.
51. Kurth, L. E.: Balanced Occlusion, J. Pros. Den. **4**:150, 1954.
52. Downs, B. H.: Unpublished paper read at the meeting of the Academy of Denture Prosthetics, Colorado Springs, Colo., May, 1956.
53. Trapozzano, V. R.: An Analysis of Current Concepts of Occlusion, J. Pros. Den. **5**:764-782, 1955.

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DISCUSSION

OF

The Transograph and Transographic Articulation by Jerome M. Schweitzer, D.D.S.

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DR. SCHWEITZER IS TO be congratulated on his efforts to clarify the concepts of "Transographics." I have read the available original subject material relating to these "concepts." It was my opinion after reading these articles, and it is now, that many of the concepts of Transographics leave much to be desired.

It is stated that the principles of theory and technique of Transographics are based on the work of McCollum and the Gnathological Society. This statement is hardly warranted when we consider that the two schools of thought make an entirely different basic application of the transverse hinge axis. McCollum uses the "solid hinge axis," while in Transographics this principle is refuted, and we are told that we must use a "split hinge axis." Both schools of thought are predicated on the assumption that it is possible to locate a transverse hinge axis on a patient and to transfer this relation to an articulator successfully. Actually, it is not always possible to locate a transverse hinge axis with the fidelity of a true hinge. Frequently, when attempting to make this registration, it will be found impossible to obtain absolute rotational movement of the stylus because of asymmetry of the condyles.

The inventor of the Transograph recognizes this situation. "The irregular condyles make it impossible for the various individual axes [including the transverse hinge axis] to be constant, even in simple rotation." As a solution, he offers us the idea of a transverse "split" hinge axis by which one may purportedly overcome this objection. That this solution is not acceptable will be immediately manifest when it is remembered that the primary difficulty still lies in the making of the transverse hinge-axis registration on the patient, that is, when rotational movement on the transverse hinge-axis plane is not a true rotational movement. In making a transverse hinge-axis registration on the patient, there is no essential difference in the technique offered by the inventor of Transographics and any similar procedure with which I am acquainted. The inherent potential error is always present.

Next, it is implied that the Transograph has no mechanical connection between the two bearings as in a "solid axis" articulator. We are told that "the Transograph has its condylar bearings joined only by means of casts that represent and duplicate the patient's maxillary and mandibular arches." This is essentially no different from the connection used on other articulators. The end

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result is that both machines have a solid attachment, one through the solid axis connecting the posts, and the other (the Transograph) connecting the posts through the casts. The fact that the latter is claimed to be better because "the condyles have their junction in the symphysis which is an offset point" is in no way significant.

Let us consider the concept of the transverse split hinge axis and that each axial center is independent of the other. In accordance with this concept, each condyle rotates around a different axis, and this difference in axes is provided for in the articulator by means of the "split axis." The implication of this concept I cannot accept. During embryonic life, the two bones which form the mandible fuse together, and by the time of birth they form one rigidly connected body. Movement of one part of any body must be accompanied by collateral movement in all other parts of that body. Obviously then, the transverse rotation of one condyle is accompanied by a simultaneous rotation of the other condyle and, within any definite segment of an arc, must rotate on a common center (either actual or the center of the loci). To do other than this, two things would have to happen: (1) the mandible would have to bend, or (2) the continuity of the mandible must be broken. Of course, neither of these two situations occurs.

Since in setting the "Transograph," a so-called split axis is used, it is only natural that the articulator (posts?) bend when the arc of rotation exceeds the confines of the relative rigidity of the metal parts. If it is implied that this bending, or as Dr. Schweitzer states, "flexibility" of the articulator is a controlled action, I must take exception and state that it is not correct. Actually, what happens is that when the hinge axes are mounted at different levels, rotation still occurs through an imaginary solid hinge axis. This latter axis represents a composite of the movement of both condyles during rotation on a transverse plane.

Dr. Schweitzer correctly states that the Bennett movement has always been looked upon as a definite bodily sideshift of the mandible during lateral jaw movements. However, in "Transographics," this concept is held to be untrue. In "Transographics," the Bennett movement is considered as a component of vertical rather than lateral movement. I want to discuss this concept of Bennett movement first, from the standpoint of lexicography and, second, from the standpoint of validity, accuracy, and application of the concept offered.

1. In assuming the role of a lexicographer, the inventor has exceeded the prerogatives of such a role. Bennett himself described the movement in question, and lexicographers have long established the use of his name to describe the movement. You may, of course, assign a different name to the movement, but you will not define what is purported to be a new concept of the movement by the use of a previously established definition and nomenclature, or confusion will result. Incidentally, this points up the value of our Glossary of Prosthodontic Terms.

2. Let us examine the inventor's concept of Bennett movement. He states,[1] ". . . a true Bennett is not a component of laterals at all but of natural functional movements, the *major one** of which is the vertical movement." The statement as it stands is not only incorrect, but is in itself ambiguous. Physiologically, the Bennett movement is the sideshift of the condyles during functional movement and

*Italics mine.

is *manifested by lateral movement and function.* To say that this movement is a major component of the vertical movement is not correct.

Actually, *there is* a slight lateral bodily shifting of the condyles during the transverse hinge-axis movement, independent of the Bennett movement, which follows a well-known physical law. To clarify this point, imagine two uprights, or their equivalent, set up in a manner similar to the two posterior posts of an articulator. These posts will form the supporting swing for the suspension of the mandible (roughly to the fossae) with the condyles resting on the supports. The condyles need not be suspended at the same level. Now, for the sake of simplicity, further assume that the posts are set up parallel to each other by any means. It still follows that by a common law in physics, no two lines are perfectly parallel to each other; therefore, any swing on the mandible *will include* some lateral shifting, *but* the amount of lateral shifting is almost infinitesimal (except in rare cases of extreme asymmetry of the condyles) and practically impossible to capture, let alone transfer to an articulator. Bennett movement as defined by the inventor of Transographics is, therefore, untenable and incorrect.

We are told that the machine (Transograph) constructed to utilize these concepts will permit the machine, ". . . to accept instantly and perfectly wax bites of widely varying thicknesses and bite depths on any given dentulous case."[2] A machine can utilize only those records which are put into it, which, in this instance, consist essentially of the "transverse hinge axis," cranial plane determination, and the wax interocclusal record. Thus, the machine is far from a pantograph. I accept Dr. Schweitzer's statement that, when a wax interocclusal record is inserted in the patient's mouth and he is asked to chew it, this wax interocclusal record with the chewing paths will be accepted by the "Transograph," indicating that the pantographs of the chewing angles may be correct. However, I agree for a reason entirely different from that implied by Dr. Schweitzer. I believe it may be possible for the Transograph to accept any "chew-in" which the patient may produce, *but* it will do so not because it is acting as a pantograph, but rather because of the presence of the uncontrolled free-acting joints which are built into the machine.

There is much in this presentation which time will not permit me to discuss. In closing, I would say that *any* of the concepts and techniques which have been or are being used are open to considerable criticism; however, I am left with the feeling that Transographics promises much more than it delivers.

REFERENCES

1. Page, Harry L.: Occlusal Movements and Obstructions: The Bennett Movement—Part Two, D. Digest **61**:397, 1955.
2. Page, Harry L.: The Bennett Movement, D. Digest **57**:413, 1951.

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THE USE OF PORCELAIN AND PLASTIC TEETH IN OPPOSING COMPLETE DENTURES

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THE CO-USE OF PORCELAIN teeth for one denture and plastic teeth for the opposing denture presents an interesting compromise of the physical properties of the two materials. It was discovered that greater wear resistance and masticating efficiency was produced than with plastic-versus-plastic teeth. Compared with dentures using all porcelain teeth, it is easier to bring them into the desired occlusion by grinding mainly the plastic teeth. Similarly, the dentures will tend to adjust themselves into occlusion by "wearing-in" as plastic dentures do, but at a much slower rate. The click and trauma hazards of dentures made with all porcelain teeth are virtually eliminated because the porcelain teeth strike against plastic. Similarly, the probability of failure of porcelain teeth through impact is reduced. The principle applies to the anterior as well as the posterior teeth.

COMPARATIVE MERITS OF PORCELAIN AND PLASTIC TEETH

Docking[1] made a rather complete analysis of this subject. His criticisms of porcelain and plastic teeth are derived from a survey of a number of cooperating dentists in Australia. He lists reduced masticating efficiency, cold flow, wear, and staining as some of the major disadvantages of plastic teeth. For advantages, he includes toughness, resilience, ease of grinding and polishing, and freedom from the noise of click and trauma.

For porcelain teeth, on the other hand, he lists as advantages the high surface hardness which aids in mastication and the extreme abrasion resistance. As objections to porcelain, he lists brittleness and friability which lead to chipping. Also, he lists noise, click, and trauma, which result from their extreme hardness and which may be accentuated by an improper occlusion.

Dirksen[2] refers to the fact that plastic teeth wear down and cites it as an advantage in so far as it allows balanced occlusion to follow the settling of the dentures. He considers the wear of plastic teeth as a disadvantage because of the loss of masticating efficiency through the wear of cutting edges, cusps, and mechanical features of the teeth and because of the loss of vertical dimension.

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THEORY OF THE IMPROVEMENTS FOUND

Since most of the demerits still associated with improved cross-linked polymer teeth are derived from the loss by wear of the sharp cutting surfaces or the loss of occlusal structure, a study of the causes of wear is in order. It is felt that there are two principal causes for abrasion of plastic teeth in the mouth: (1) The saliva-lubricated abrasion against the opposing teeth. This is accentuated by nervous habits, such as night or day bruxism. (2) The grinding of foreign matter between the teeth.

In mastication probably both are combined, the extent of the wear varying with chewing habits. Yurkstas and Emerson[8] showed that there is a high percentage of contact of teeth during mastication, both on balancing and working sides of the denture.

The theory for the reduction in wear when porcelain teeth oppose plastic teeth, in the saliva-lubricated abrasion, is based largely on principles taught in elementary physics. The coefficient of friction of like materials is often greater than that of unlike materials, and the coefficient of friction between soft materials is greater than that between a soft and a hard material as a general rule. The use of brass, bronze, or Babbit bearings for steel shafts, rather than steel bearings, is evidence of this. It is well known that a polished diamond needle is very satisfactory for the life of phonograph records. This is due to the fact that, in use, the diamond needle tends to retain its smooth surface and continues to be less abrasive and less cutting. If the porcelain surface is a good bearing surface, that is, if it is smooth and without sharp cutting edges, it will produce considerably less attrition on the plastic surface than would a similarly smooth plastic surface.

We assume in other types of wear, as is the case where there is a foreign body between porcelain teeth and plastic teeth, the rate of wear will be approximately half that of plastic-versus-plastic teeth. This assumption is based on the clinical evidence that, except in rare instances, the wear of porcelain teeth in oral conditions is negligible, and on the assumption that forces involved in chewing will be the same as in the all-plastic dentures. Hence, plastic teeth, in the combination of plastic versus porcelain, will be opposing a foreign body in much the same condition as if they were *part* of a plastic-versus-plastic combination. In this way, the wear on the plastic teeth would be the same as on either set of the plastic teeth opposing each other. However, since porcelain teeth show negligible wear, the total vertical dimension loss to the dentures would be one-half that of the plastic teeth versus plastic teeth. Perhaps more important is the fact that the mechanical surfaces of the teeth of one denture, at least, would be left intact.

SPECIFICATIONS FOR USE

The rules for the use of this combination are simple, but they must be applied for satisfactory results.

1. The porcelain teeth must be smooth, polished or glazed, and free from sharp cutting edges. The flat cusp, zero degree, nonanatomic type of tooth is superior to other types. However, the porcelain teeth should have cutting ridges to allow for the mastication of the food, and they should have flat bearing areas that will prevent the cutting ridges from cutting into the plastic tooth.

2. The porcelain in the tooth should be dense and virtually free from pores so that, if it is necessary, a smooth surface will be generated in wear or in grinding. The porcelain tooth should be smooth in its original shape from the firing operation.

3. All necessary grinding should be done on the plastic teeth, if possible, to retain the fired surface on the porcelain teeth. If it is necessary to grind the porcelain teeth, a polished surface free from sharp ridges should be restored on the tooth. This can be done by: first, finishing the grinding with a rubber wheel; second, smoothing the ground surface with pumice; and third, polishing to a gloss with a material such as fine flour of pumice or tin oxide.

4. The plastic material in the plastic teeth should be as abrasion resistant as is available and should be cross-linked for durability.

In order to emphasize the importance of the specifications list, it should be mentioned that there is contrary evidence to this theory in the literature. Greenwood[4] found, both clinically and in his laboratory work, that plastic teeth opposing porcelain teeth produced results inferior to those with plastic teeth opposing plastic teeth. He did state, however, that the teeth were ground into occlusion prior to starting both the clinical and laboratory tests. This could have produced a rough surface unless it was polished. He did not specify the denseness of the porcelain teeth or the type of plastic in the plastic teeth. Naturally, a rough ground porcelain surface would act as an abrasive on the plastic tooth, and wear would be considerably accelerated. It is felt that Greenwood's contrary results must in some way be connected with this surface condition.

OTHER ADVANTAGES

Click or trauma is virtually eliminated because the teeth are porcelain hitting plastic instead of being porcelain hitting porcelain. The yielding character of the plastic absorbs some of the energy of impact and reduces the noise.

The hazard of friability and brittleness of the porcelain itself is corrected because the impact is delivered by the plastic tooth.

Another of the disadvantages of plastic teeth is the loss of the cutting surfaces and mechanical features of the teeth. When porcelain teeth are used opposing plastic teeth, the porcelain teeth retain their cutting edges so that at least a portion of the mechanical feature is retained. By designing the teeth so that there is a "knife on a chopping block" action, cutting efficiency can be retained. The teeth used in the tests to be described meet the specifications listed above. The occlusal surfaces designed for both the porcelain and plastic teeth were of the nonanatomic type, having flat milling areas, sharp cutting areas, and adequate spillways.

METHOD

The method used in this laboratory wear test was to abrade the teeth to be tested against each other for a known period of time, in a liquid bath containing the abrasive desired, and under a known load. The wear test machine is shown

in Fig. 1. The teeth were weighed before and after each test. The results are reported in terms of volume loss, because of the difference of specific gravity between porcelain and plastic teeth. Porcelain teeth have approximately twice the density of plastic teeth. The data reported are a composite of more than 200 trials. Posterior teeth were used on all the tests.

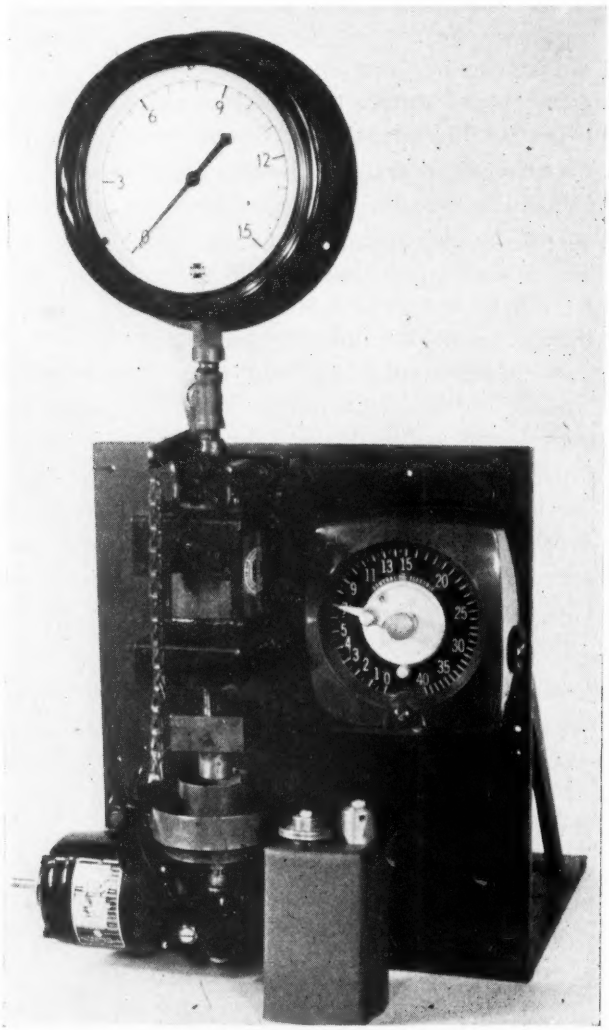

Fig. 1.—The wear test machine.

EFFECT OF LOAD

The first series of tests were relatively short runs with a pumice and water bath and a varying load on the teeth (Fig. 2). It can be seen that as the load is varied, the rate of loss is much less on the porcelain-versus-plastic teeth than on plastic-versus-plastic teeth. The average ratio seems to be about 6½ times the volume loss of the plastic-versus-plastic teeth than of the plastic-versus-porcelain

teeth. It is to be noted that in the curve for the plastic-versus-plastic teeth there is a point, similar to an elastic limit, at which the rate of loss increases very rapidly. This test set-up corresponds to a load of approximately 28 pounds. It is interesting to note that the combination of plastic-versus-porcelain teeth has the same type of critical limit and that is at about 28 pounds, which is similar to results found with plastic-versus-plastic teeth. In order to show this we have multiplied the volume loss for the porcelain-versus-plastic teeth by 10, and it shows the similarity in the third curve (Fig. 2).

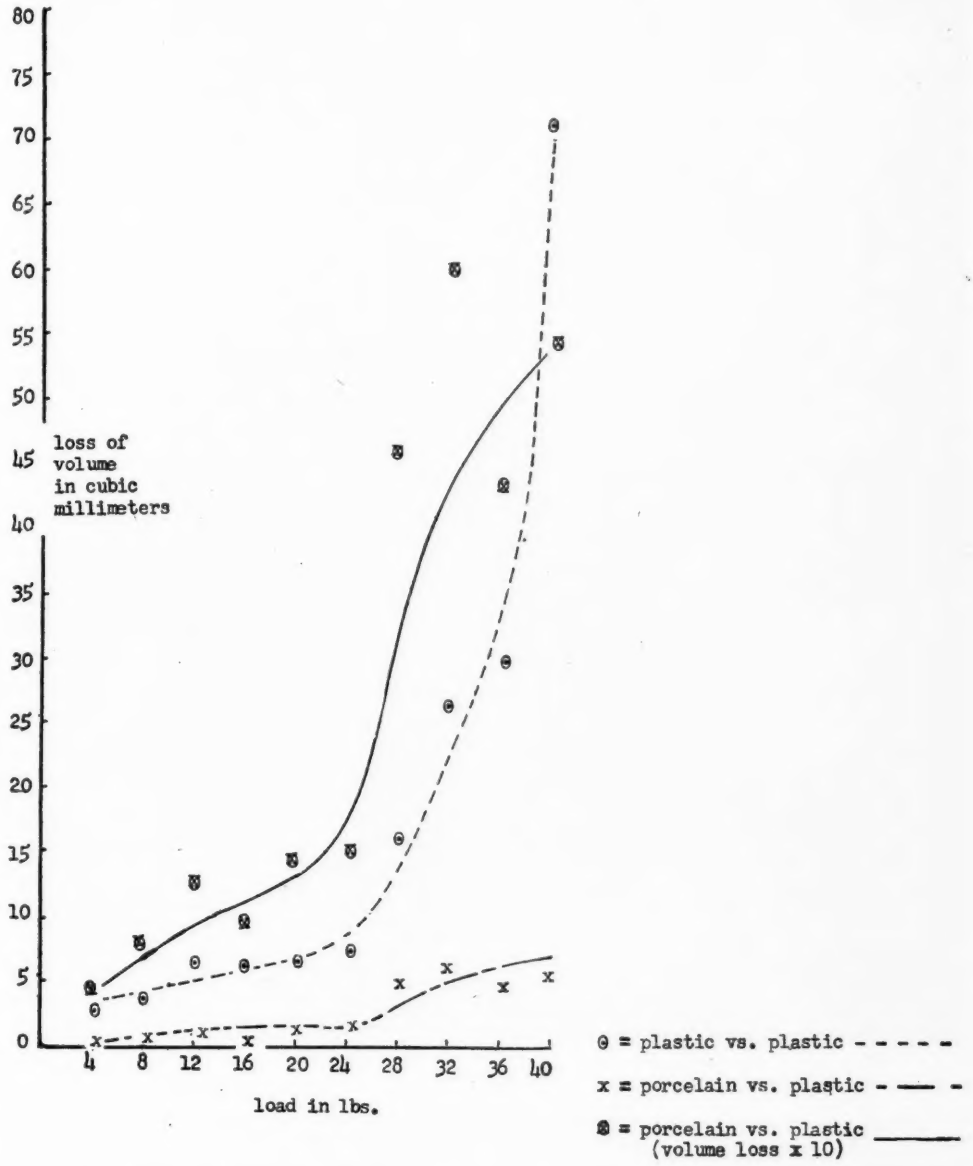

Fig. 2.—Abrasion resistance shown in relation to load on teeth with a constant abrasive.

Fig. 3.

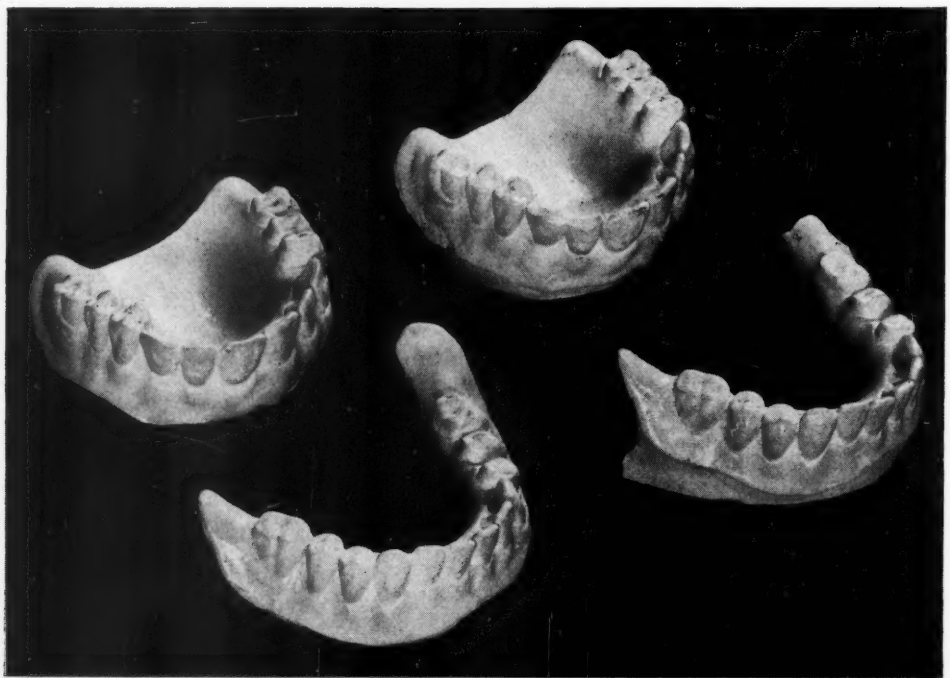

Fig. 4.

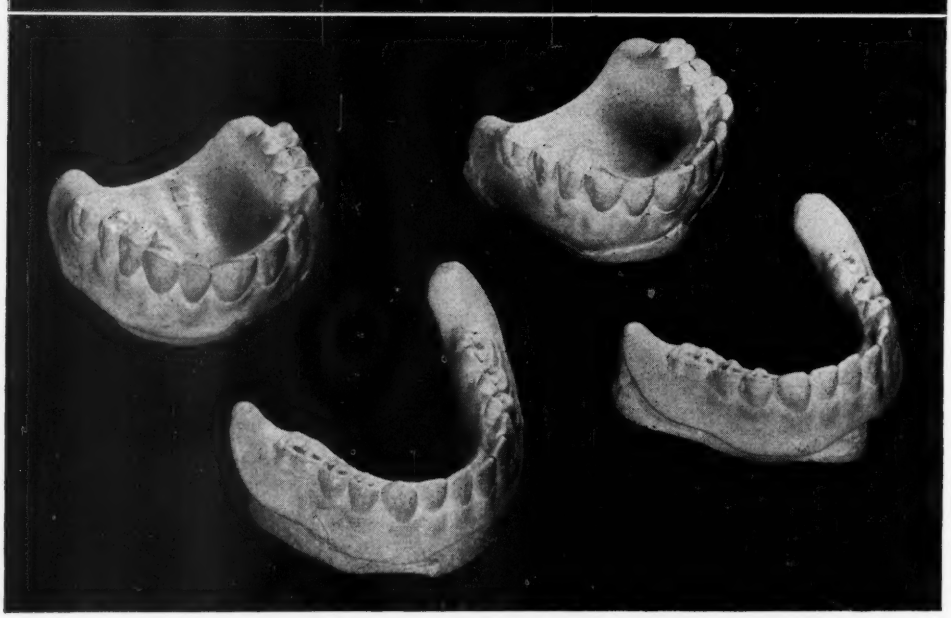

Fig. 3.—Stone models made from dentures showing the wear that takes place when plastic teeth oppose plastic teeth. The models on the left reprcsent the dentures at the time of insertion. The models on the right four months later. Note the dulled condition of the occlusal surfaces.

Fig. 4.—Stone models made from dentures showing the wear where lower posterior porcelain teeth oppose upper plastic teeth (same patient as in Fig. 4). *Left,* at the time of insertion; *Right,* two and one-half years later.

EFFECT OF ABRASIVES

The load was held constant at 12 pounds in the next series of tests and the type abrasive used in the bath was varied (Table I). It was found that the use of harsher abrasives tended to narrow the difference between the two types of occluding materials. When carborundum, suspended in a water medium, was used as an abrasive, the superiority of the porcelain-versus-plastic teeth was 2.05 to 1.0. With a moderate grade of feldspar (minus 200 mesh), the superiority was 3.5 to 1.0. With talc, the superiority was 7.2 to 1.0. Finally, in a series run in water with 5,800 revolutions, the superiority of the porcelain versus plastic was 11.6 to 1.0.

TABLE I. THE VARIATION OF ABRASION RESISTANCE WITH VARIOUS ABRASIVES WITH A CONSTANT LOAD. (LOAD CONSTANT TWELVE POUNDS.)

ABRASIVE	REVOLUTIONS	LOSS PORC. VS. PLASTIC CUBIC MILLIMETERS	LOSS PLASTIC VS. PLASTIC CUBIC MILLIMETERS	SUPERIORITY OF PORC. VS. PLASTIC
Carborundum and water	500	8.8	18.1	2.05/1
Feldspar and water	500	4.7	16.3	3.5/1
Talc and water	500	0.34	2.4	7.2/1
Water alone	5,800	0.95	11.0	11.6/1

The variation of the ratio with the abrasive is seen with the most improvement occurring where no abrasive material was used and when we merely tested the effect of the teeth rubbing against each other. This confirms the theory that the wear is considerably less in the water-lubricated or saliva-lubricated abrasion of the porcelain-versus-plastic teeth than in the plastic-versus-plastic teeth. As foreign bodies are introduced into the masticatory system, more wear will take place in the plastic-versus-porcelain tooth combination, and its superiority will be narrowed.

The results of the laboratory tests are in accord with the theory that the porcelain-versus-plastic teeth will show a greater wear resistance than plastic-versus-plastic teeth.

CLINICAL DATA

Sears[5] reports that in ten years of experimenting with various tooth materials in the mouths of patients, the "porcelain-to-plastic is more wear-resistant than plastic-to-plastic." Dr. Simon Myerson, in cooperative effort with the author, has started a series of clinical cases. The subjective judgment after a year is highly satisfactory. Very little wear has taken place, and the patients appear to be well satisfied with the dentures. The wear in Figs. 3 and 4 is the result in an extremely severe clinical case, and that in Fig. 5 of a more or less typical test.

Dentures with all plastic teeth were made for a patient (Fig. 3). After four months, the teeth on these dentures were badly worn. This, we feel, was due to the fact that she is a robust factory worker who has a nervous habit of constantly grinding her teeth with an oblique forward motion while working. The wear in the bicuspid area during this period was a total of 1.0 mm. for the two dentures, in other words, 0.5 mm. in each denture (Fig. 3). The anterior teeth suffered more dramatically due to the nature of her grinding action. It is important to note that the cutting edges of the posterior teeth were badly dulled. New dentures were made. The upper denture had plastic teeth throughout, and the lower denture had porcelain posterior teeth and plastic anterior teeth. When the new combination was inserted and the occlusion properly adjusted, impressions of the dentures were made, and models were made from them. Impressions were made at regular intervals. After 3 months of wear, only traces of attrition were visible on the plastic teeth.

After 2½ years of wear, there was no measurable wear in the porcelain bicuspid area as can be seen in Fig. 4. In the plastic teeth, there was an average wear of slightly less than 0.5 mm. The total wear on the plastic section was approximately the same as on each denture in the plastic-versus-plastic teeth in 4 months. The total wear, however, is less than half because of the fact that the porcelain teeth show no attrition.

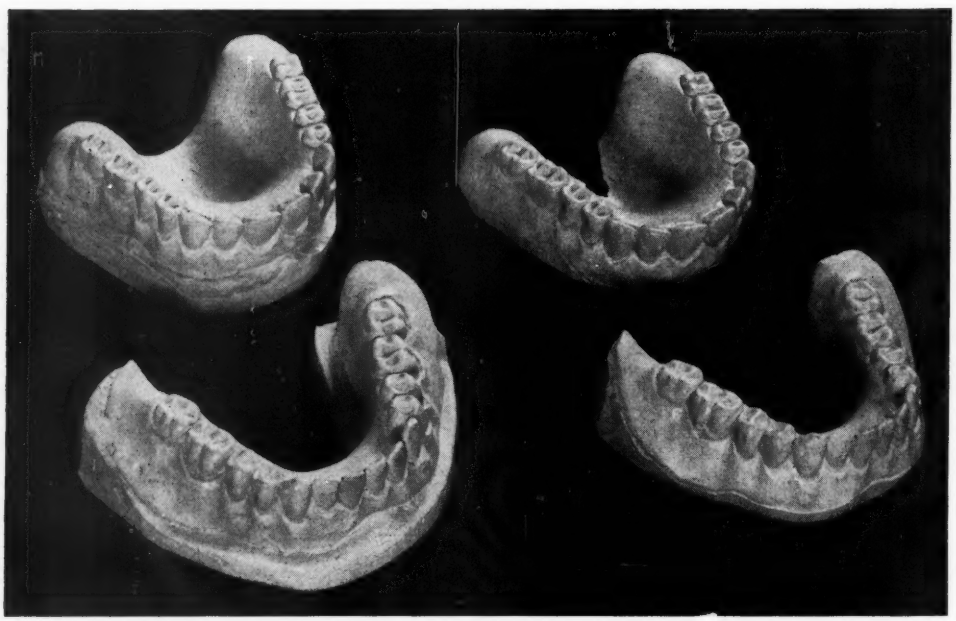

Fig. 5.—Stone models made from dentures show accommodating wear on the lingual cusps of the lower left second molar. *Left,* models made from dentures at the time of insertion; *Right,* six months later. The upper teeth are porcelain.

It is of extreme importance that the condition of the cutting edges of the porcelain teeth are completely intact. They provide efficient mastication after 2½ years, whereas the cutting edges of the teeth were badly dulled in four months when plastic teeth opposed plastic teeth.

Despite the habitual protrusive action, there has been no failure or fracture of the porcelain teeth. In previous dentures with opposing porcelain teeth, this patient fractured the porcelain cusps because of this grinding habit.

Dentures with plastic teeth opposed by porcelain teeth were made for a heavy-set man in his forties (Fig. 5). They have been in the mouth for approximately six months and, as yet, they do not show any significant wear. The extreme sharpness of the upper porcelain posterior teeth can be noted, and some accommodating wear has taken place locally in the plastic teeth. The left second molar shows flattened spots on the lingual cusp surfaces where the teeth were striking slightly hard on insertion. Apart from this, the cutting edges of all the plastic teeth are virtually intact.

SUMMARY

The features of the combination of plastic teeth with porcelain teeth are:

1. It is easy to bring the dentures into occlusion by grinding mainly the plastic teeth.
2. Wear is not completely eliminated so some accommodation by wear occurs.
3. The hazard of click and trauma is virtually eliminated because porcelain teeth occlude against plastic teeth.
4. Because of the yielding character of the plastic teeth, much of the energy of impact is absorbed, and this compensates for the hazard of friability and brittleness of porcelain teeth.
5. Masticating efficiency is maintained at a higher level than with plastic teeth versus plastic teeth because the mechanical cutting edges of the porcelain teeth will not be lost.
6. There are simple rules to be followed in using plastic teeth against porcelain teeth. These should be emphasized. The porcelain teeth should present smooth polished surfaces, with no cutting action into the plastic teeth, at all times. This is done best by using a flat cusp type of tooth made of dense porcelain.

This combination of porcelain and plastic teeth represents a compromise. The trauma or click is somewhat greater with the plastic and porcelain combination than with the plastic teeth opposed by plastic teeth. Cutting efficiency is greater than with plastic-against-plastic teeth, but less than porcelain-versus-porcelain teeth.

This is a preliminary report. Further investigation is being carried out in both the clinical and the laboratory aspects of the problem. It has been reported at this time because it is felt that the compromise of the properties of the plastic teeth and porcelain teeth is successfully achieved by their co-use, and that this compromise is worthy of consideration.

REFERENCES

1. Docking A. R.: Relative Merits of Porcelain and Acrylic Teeth, D. J. Australia **23**:173-182, 1951.
2. Dirksen, Lynn C.: Plastic Teeth: Their Advantages, Disadvantages, and Limitations, J.A.D.A. **44**:265-268, 1952.
3. Yurkstas, A. A., and Emerson, W. H.: A Study of Tooth Contact During Mastication With Artificial Dentures, J. Pros. Den. **4**:168-174, 1954.
4. Greenwood, A. R. T. (Commonwealth of Australia Dept. of Health): The Wear Resistance of Synthetic Resin Teeth. Thesis submitted Dec. 8, 1952.
5. Sears, Victor H.: Occlusal Pivots, J. Pros. Den. **6**:332-338, 1956.

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THE EFFECT OF VARIOUS GEOMETRIC OCCLUSAL PATTERNS ON CHEWING EFFICIENCY

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CONSIDERABLE CONTROVERSY HAS existed in the dental profession regarding the chewing efficiency of various types of commercially available teeth. Proponents of each tooth type are at variance with one another as far as the advantages of any given tooth form is concerned.[1-9] The tooth forms currently available represent the results of many years of clinical experience, keen observation, admirable ingenuity, and remarkable visual imagery on the part of their designers. For the most part, however, the various tooth forms do not appear to have been designed with the benefit of adequate scientific inquiry into the why or how of their efficiency. For this reason, a study was undertaken to evaluate the effect of various basic straight-line geometric carvings on masticatory efficiency under various experimental conditions. This study was limited to occlusal forms which could be classified as nonanatomic teeth.

Our definition of nonanatomic teeth coincided with the reasoning of Sears.[10] He defined nonanatomic teeth as ". . . teeth designed on a mechanical basis rather than anatomic basis." He stated further that "the working occlusal surfaces should be void of cusps or inclined planes that might hinder the free horizontal gliding of opposing surfaces as the alveolar ridges resorb or as the mandible carries the teeth into protrusive occlusion," or ". . . as the mandible carries the teeth laterally." The design of this research was based on these postulates in that two occluding horizontal planes upon which a number of mechanical designs could be carved, obliterated with self-curing resin, and then recarved, were used as posterior tooth members.

REVIEW OF THE LITERATURE

It might be well to review the literature dealing with the relative efficiency of various types of commercially available tooth forms in persons wearing dentures. We must emphasize, however, that there are many factors which influence masticatory efficiency of dentures other than the teeth themselves. Some of these factors

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The opinions or conclusions contained in this article are those of the authors and are not to be construed as official or reflecting the views of the Army Department or the United States Army at large.

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may include the type of patient, the condition of the residual ridge, the type of denture, the amount of biting force, the character of the test food, the size of the bolus, the relative position or placement of teeth, etc. It is, therefore, very important that the tests designed to evaluate the relative efficiency of tooth forms conform to rigidly controlled experimental conditions. Among the most important conditions that must be fulfilled is that the testing procedures are conducted on the same patient with the same denture bases but with different types of occlusal configurations.

Thompson[11] conducted a series of masticatory performance tests using two anatomic and two nonanatomic types of teeth. He found a relatively high performance of 65 per cent when he utilized 33 degree teeth, and then in order of decreasing efficiency, Hall's inverted cusp teeth 58 per cent, 20 degree posterior teeth 57 per cent and Sears channel teeth 29 per cent. The teeth designed by Hall and Sears were nonanatomic carvings. Manly and Vinton[12] in a cross-section study of 100 denture wearers showed that there was no difference between the performance of 50 individuals who wore dentures with nonanatomic teeth and 29 individuals who presented anatomic teeth. In a more selected group of 20 full denture wearers, the same workers[13] concluded that masticatory performance was greater with nonanatomic teeth than with anatomic teeth. The nonanatomic teeth in this study consisted of a mixture of French's posteriors (Universal), "H" mold posteriors (Austenal), and 0 degree posteriors (Justi). Payne[14] described tests on one subject using duplicate complete upper and lower dentures, one with 33 degree anatomic posterior teeth and the other with nonanatomic posterior teeth. He quoted no performance figures but did quote the observations of the denture wearer himself. He concluded that anatomic posterior teeth were more efficient when carrots and peanuts were used as test foods.

Trapozzano and Lazzari[15] reported chewing tests conducted on two denture wearers with three types of artificial teeth. Their methods were an extension of Thompson's earlier work. While no conclusions were drawn from their limited numbers of tests, the data presented appeared to indicate that the modified anatomic teeth, 20 degree posteriors, resulted in higher performance with carrots and peanuts than the nonanatomic types of Hall and DeVan.

Probably the most interesting account of experimental comparison of posterior tooth forms was given by Sobolik.[16] He constructed duplicate dentures in his own mouth where he tested the comfort, stability, and performance of five types of artificial posterior teeth. Three of these fulfilled the definition of nonanatomic posterior teeth. He tested performance with lettuce, apples, almonds, and boiled ham and concluded that no one form was superior to the others with all foods. However, from his data tables, the French's and Tru-Kusp forms appeared to give uniformly better performance figures than did Hall's inverted cusp teeth. In an unpublished study, conducted in 1940 at the Houston meeting of the Academy of Denture Prosthetics[17] in which a half dozen or more types of teeth were tested, it was indicated that the teeth that were most efficient on carrots were French's type posterior teeth which had been recut by Blanchard so that their occlusal surfaces had sharp cutting blades running buccolingually on the lower teeth.

It is apparent from this brief survey that available comparisons of efficiency among nonanatomic posterior tooth forms are relatively few. Thompson's results

seem to indicate that Hall's tooth had some superiority over Sears tooth, and from the work of Trapozzano and Lazzari, evidence was presented to show that, in one instance, DeVan's teeth were superior to Hall's, while in another the performance scores were reversed. This would appear to give Hall's teeth questionable advantage over the other two, all of which is negated by Sobolik's findings of better performance with the French and Tru-Kusp forms.

It was apparent that further scientific work had to be accomplished in an effort to understand the problem of masticatory efficiency with various types of occlusal surfaces. The present study was undertaken without reference to existing commercial patterns. It was decided to test the efficiency of two occluding horizontal planes upon which could be carved a number of mechanical designs. In a series of tests using a variety of geometric designs and combinations of designs, it was hoped that some patterns would result in higher efficiency than others. By careful evaluation of the results, perhaps certain basic principles of mechanical advantage in occlusal forms could be discovered. Occlusal patterns for artificial teeth should certainly receive their ultimate testing in the mouths of complete denture wearers. In as basic a work as this study proposed, however, such a procedure was wrought with hazard. For example, the critics of nonanatomic artificial teeth placed as much weight upon balance as they did upon performance. Therefore, if testing were summarily carried out in edentulous mouths, balance would have to be given equal weight with performance. The aim of this study was to consider performance by a noncusped apparatus as divorced from such factors as excellence of denture bases, ridge relationships, adherence to a given technique, balance, etc. For this reason, mouths possessing a nearly normal dentition were utilized in this study.

Fig. 1.—The test appliances in the mouth.

PROCEDURE

Appliances were built to provide an overlay of material upon the occlusal surfaces of the natural posterior teeth (Fig. 1). The thickness of this overlay was sufficient to permit the carving of subocclusal areas 1.0 mm. in depth and 1.0 mm. in width. While it may be argued that subocclusal areas should be deeper or shallower than this amount to function properly, this depth was used as a constant

to operate in all patterns tested. By imposing a layer of material upon the occlusal surfaces of the lower posterior teeth, and a similar layer upon the upper teeth, the mandible was prevented from closing to the previous vertical dimension. In essence, the appliances were a "bite opening" device. The average opening in 5 subjects as measured between the interdental papilla of the upper and lower central incisors was 8.0 mm. (Fig. 2). It was realized that "bite opening," as such, may reduce chewing efficiency, or it may alter the normal chewing cycle. This was not thought of as offering particular prejudice to the experiment, as the hazard operated uniformly in all patterns tested. If some one or several of the patterns showed evidence of a superior performance as compared to the others, it would not be because of the "bite opening" or the adherence to a special technique, balance, or other factors, but because of the mechanical superiority of the occlusal pattern itself.

The appliances were constructed of methyl methacrylate resin. Details of their construction will not be considered in this publication. It should be emphasized, however, that extreme care was taken to ascertain that the planes were in relatively perfect centric occlusion. This was determined by articulating paper and by the utilization of a strip of softened opaque wax.[18] When the wax was uniformly expressed between the planes and a clear imprint of the occluding areas was identifiable, the planes were considered to be in good occlusion.

Fig. 2.—Extraoral view of the test appliances.

DETERMINATION OF MASTICATORY PERFORMANCE

Efforts were made to include materials representative of several classes of foods ordinarily found in the diet. Our interest was directed toward the physical qualities rather than to the nutritive content of the test foods. We can conceivably classify foods as being liquid, soft, friable, fibrous, or viscous. It seemed that the friable and fibrous foods made up the largest part of the diet which required chewing ability for enjoyment or utilization. Most investigators have used nuts as a representative of friable foods. Peanuts were selected because of their ease of procurability, adaptability to the test methods, universal taste appeal, and the fact that results could be compared to other works using the same test foods. Planters

Cocktail Peanuts packed in 8-ounce packages were used throughout the experimental procedure. Carrots were the most widely used vegetable in the class of fibrous test foods. Their use was easily justified from the standpoint of availability and taste appeal. Efforts were made to select carrots of uniform size, freshness, and fiber content, but no guarantee existed that this could always be done. In spite of this, the carrots were used as an example of fibrous foods throughout the testing period. It was reasoned that while carrots may be representative of vegetable type fibrous foods, there was no assurance that, in the mouths of the denture wearers, carrots would act similarly to meat fibers. Hence, ham was also included to provide variety of test materials. Six-pound, cooked hams were procured from the Armour Packing Company. Muscles of uniform fiber length and consistency were dissected, wrapped individually in metal foil, and stored in the refrigerator.

Test foods were all prepared in 3 Gm. samples, within limits of plus or minus 0.5 Gm. The peanuts were used as they came from the can. Carrots were cut in 6 equal portions, and ham was presented as a single bite size, 3 Gm. portion. The volumetric methods for determining masticatory performance as described by Yurkstas and Manly[19, 20] were used during this testing procedure. In brief, masticatory performance with peanuts was determined by calculating the percentage of peanuts passing through a 10 mesh screen after a given number of masticatory strokes. Carrots and ham performance was determined as the percentage of particles passing through a 5 mesh screen with the residue being collected on a 100 mesh screen.

After a number of trials with blank, unscored occlusal surfaces and various numbers of strokes, the number of chewing strokes used during testing procedures were as follows: peanuts 15 strokes, carrots 25 strokes, and ham 15 strokes. The performance scores that resulted were in the middle range, thus allowing for an increase or decrease in score as additional patterns were tested. Five individuals joined in the program. Right and left sides of each were considered separately. Tests were accomplished in duplicate with each pattern on one day, and then single tests with carrots, peanuts, and ham were repeated on a subsequent day. When a variation of more than 5 points was displayed between the tests on the same test food on different days by any one subject, the whole series involved was repeated. This resulted in the total of 962 valid tests.

OCCLUSAL CARVINGS

In an attempt to produce shearing or cutting elements on the occlusal surfaces of the appliances used in the study, grooves were cut in the surface of the overlays. A mounted stone was used to make the cuts which were uniformly 1.0 mm. in depth and 1.0 mm. in width. The grooves were spaced 5.0 mm. apart as measured from their center. This resulted in a flat ungrooved surface approximately 4.0 mm. between grooves. Where both upper and lower surfaces were to be grooved, the appliances were placed in the mouth after first preparing the upper one. The lower one was marked while the appliances were held in occlusion, and the lower grooves were then cut to intersect the blank spaces of the upper appliances. Engagement of grooves that caused tripping when chewing motions were performed was eliminated in this way. Cup patterns were made with the aid of a pear-

shaped stone; the edges of these indentations were kept as sharp as possible. Fig. 3 illustrates in graphic fashion the manner in which the grooves were arranged on each appliance and the combinations in which they were used. Fig. 4 shows the actual occlusal contact area of one of the appliances under test conditions.

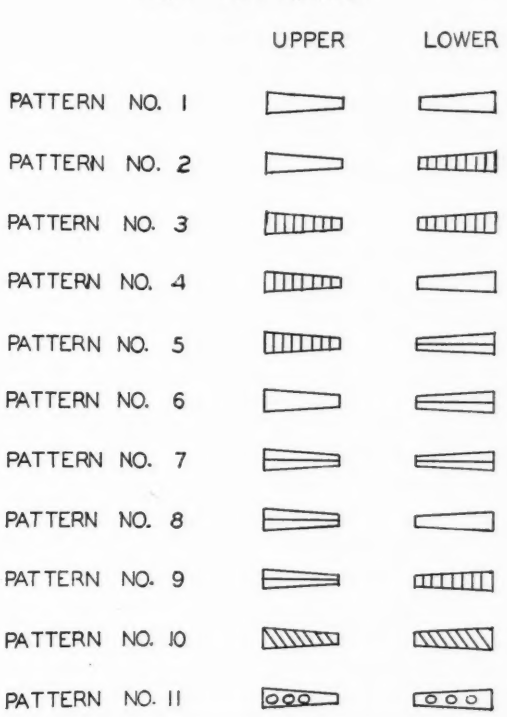

Fig. 3.—Graphic representation of test patterns studied.

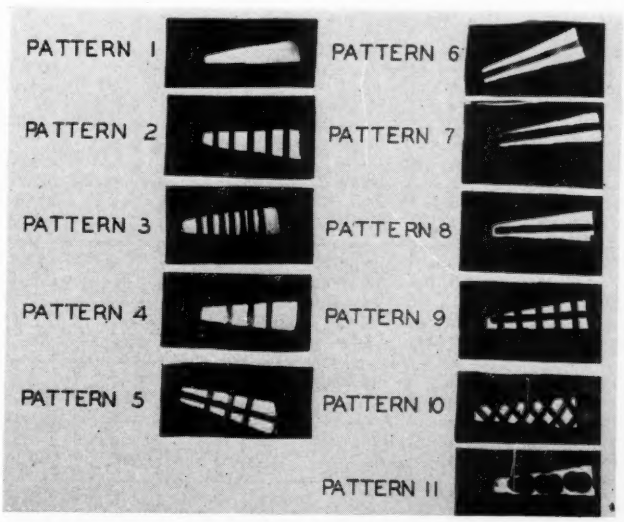

Fig. 4.—The occlusal contact areas as shown through opaque wax registrations.

When testing with one pattern was completed, the grooves were obliterated with the use of an activated acrylic resin. The mass of plastic material was placed evenly over the occlusal area of the appliance. The appliance was then placed, occlusal surface downward, upon a glass slab. By exerting pressure with the fingers, the excess material was forced to the side, and a dense mass resulted in the areas which had been cut out previously. When this blanking out process was completed, the excess acrylic resin was ground from the edges. The occlusal surfaces were sanded, smoothed, and checked in the mouth. When maximum contact of the occlusal surfaces was obtained, a new pattern was then prepared. The patterns were presented to the patient in a random fashion. This precluded the possibility of learning factors playing any part in the final results.

RESULTS

A summary of the data is presented in four tables. Table I indicates the mean performance and rank order scores using peanuts as a test food at 15 strokes for a 3 Gm. sample. Table II is a summary of the data obtained with carrots as a test food using 25 strokes for a 3 Gm. sample, and Table III is a summary of the data obtained with ham as a test food at 15 strokes for a 3 Gm. portion. The actual performance figures are indicated in bold numbers while the relative rank is indicated in small figures superiorly placed.

TABLE I. MEAN PERFORMANCE AND RANK ORDER SCORES WITH PEANUTS AT 15 STROKES

SUBJECT	PATTERN NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
A	^{9}52	^{10}50	^{8}53	^{5}56	^{7}55	$^{2.5}$59	^{1}62	^{11}48	$^{2.5}$59	^{4}57	^{6}—
B	^{5}54	^{10}49	^{7}53	^{9}50	^{8}52	^{11}46	$^{2.5}$58	^{1}59	^{4}56	$^{2.5}$58	^{6}—
C	^{5}61	^{1}67	$^{9.5}$58	$^{7.5}$59	^{11}54	$^{9.5}$58	^{2}63	$^{3.5}$62	$^{3.5}$62	^{6}60	$^{7.5}$59
D	^{4}64	^{1}67	^{9}58	$^{10.5}$56	$^{10.5}$56	^{8}59	$^{5.5}$62	$^{2.5}$65	$^{2.5}$65	$^{5.5}$62	^{7}61
E	$^{6.5}$69	^{1}74	^{4}70	$^{8.5}$67	$^{8.5}$67	$^{10.5}$65	^{4}70	^{2}71	$^{10.5}$65	^{4}70	$^{6.5}$69
F	^{10}65	^{2}72	$^{5.5}$69	$^{5.5}$69	$^{8.5}$66	$^{8.5}$66	^{7}68	^{1}74	^{11}62	$^{3.5}$70	$^{3.5}$70
G	^{9}58	$^{6.5}$60	$^{1.5}$66	$^{6.5}$60	^{9}58	^{11}55	^{3}65	^{4}64	^{9}58	^{11}55	$^{1.5}$66
H	^{6}60	^{8}58	^{1}66	^{6}60	^{11}53	^{10}55	$^{2.5}$64	$^{2.5}$64	^{9}57	^{4}62	^{6}60
I	^{10}55	^{11}50	^{8}63	^{6}64	^{6}64	^{9}58	^{2}68	^{6}64	$^{3.5}$66	$^{3.5}$66	^{1}69
J	^{10}57	^{11}54	^{4}65	^{7}63	^{9}61	^{8}62	^{1}74	$^{5.5}$64	$^{2.5}$66	$^{5.5}$64	$^{2.5}$66

TABLE II. MEAN PERFORMANCE AND RANK ORDER SCORES WITH CARROTS AT 25 STROKES

SUBJECT	PATTERN NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
A	8.5 53	10 52	4.5 57	11 46	7 54	2.5 61	1 67	8.5 53	2.5 61	4.5 57	6 —
B	7 50	8 49	3 56	11 35	10 47	9 48	2 59	5 53	1 64	4 55	6 —
C	11 30	5 40	9.5 36	9.5 36	3 43	6.5 39	1 49	6.5 39	2 46	8 37	4 41
D	11 33	6 41	9 37	10 35	2 44	7.5 39	1 48	4.5 42	3 43	7.5 39	4.5 42
E	11 46	4 64	1 75	8.5 55	5 63	8.5 55	7 58	6 59	3 70	2 73	10 53
F	11 43	5 64	1 74	7.5 63	5 64	9 58	5 64	7.5 63	2.5 66	2.5 66	10 44
G	11 49	3.5 68	1 72	10 52	8 57	9 55	2 70	6 64	3.5 68	5 67	7 58
H	11 48	5 68	1 76	9.5 56	7 59	8 58	2 75	5 68	5 68	3 74	9.5 56
I	11 46	10 50	5 63	9 55	6 60	7.5 56	4 68	7.5 56	2 72	3 70	1 76
J	11 46	7.5 54	6 56	10 51	5 61	9 52	3 69	7.5 54	4 67	1.5 70	1.5 70

TABLE III. MEAN PERFORMANCE AND RANK ORDER SCORES WITH HAM AT 15 STROKES

SUBJECT	PATTERN NUMBER										
	1	2	3	4	5	6	7	8	9	10	11
C	11 14	2 40	9 23	8 25	5 34	10 21	3 39	4 36	7 27	1 45	6 28
D	11 18	2.5 39	10 17	7 32	4.5 35	9 24	6 33	1 41	4.5 35	2.5 39	8 30
E	5.5 42	10 36	7.5 41	11 32	7.5 41	9 37	5.5 42	1 61	3 47	4 46	2 48
F	8 40	6.5 43	6.5 43	11 27	10 28	9 32	4 48	1 70	2 58	5 44	3 56
G	11 22	3 52	4 48	8.5 38	5 44	10 24	1.5 57	1.5 57	6.5 39	8.5 38	6.5 39
H	10 29	3 54	5 45	7 38	4 48	9 32	2 59	1 61	6 42	11 24	8 37
I	10 32	11 26	9 35	6 44	5 47	8 37	1 63	2.5 57	2.5 57	7 43	4 48
J	8.5 33	8.5 33	11 25	7 40	4 46	10 30	1 61	3 53	2 60	5 44	6 42

The data were first evaluated with the purpose of discovering if there was a difference in the masticatory performance among the several patterns. Right and left sides of each individual were considered separately, and since one individual did no performance tests on ham, these data are lacking in Table III.

Mean performance scores were calculated on each of the appliances with carrots, peanuts, and ham. An order of ranks from the highest scores to the lowest scores within each pattern was then assigned. In arranging rank order, the patterns evidencing the greatest performance scores were assigned the smallest value. Therefore, those patterns which have the smallest rank figure produced the highest performance and those patterns with a high rank order had the lowest performance scores.

Sampling was accomplished in a manner that provided performance scores with each pattern on two successive days. This was done in an effort to determine the ability of the subjects to duplicate their performance from one day to another. Eighty-eight paired 15-stroke peanut tests were extracted from the data. Each of 4 subjects had performed tests on alternating days with 11 different patterns providing the paired samples. The right side scores were considered separately from the left side scores, providing 44 paired samples for each test pattern. Statistical significance was computed according to Pearson's product-moment coefficient of correlation according to the method by Gilford.[21] The coefficient of correlation with right side performance by this method was 0.463 and for the left side was 0.413. Both correlation coefficients were significant to the 1 per cent level.

TABLE IV. MASTICATORY PERFORMANCE SCORES WITH ALL TEST PATTERNS

PATTERN	TEST FOOD			
	PEANUTS	CARROTS	HAM	ALL FOODS
1	60	44	23	42
2	60	55	32	49
3	62	60	28	50
4	60	48	28	45
5	59	55	32	49
6	58	52	24	43
7	65	63	40	56
8	64	55	44	54
9	62	63	37	53
10	62	61	32	51
11	65	55	33	49
Over-all mean	61.5	5.55	318	492

In Table IV, the data have been combined for all patients and all sides with all test foods. From these results, we can see that the range of masticatory performance scores using peanuts as a test food was rather low, as it ranged from 58 per cent to 65 per cent. With carrots as a test food, the range was considerably higher, 44 per cent to 63 per cent, and with ham, 23 per cent to 44 per cent. A complete analysis of variance using the masticatory performance scores was not calculated.

Instead, statistical analysis of the data was[22] accomplished using the rank order analysis of values technique described by Moses.

The product-moment coefficients of correlation were computed using the rank order of performance scores between the three test foods. It was found that peanut performance scores were well correlated to ham performance scores, 0.71 (5 per cent significance). Ham and carrots were less well correlated 0.66 (5 per cent significance), and peanuts and carrots least well correlated, 0.56 (not significant). This seemed to indicate that carrots were a good test food for performance with a fibrous material, since ham acted considerably like peanuts in its resistance to pulverization.

DISCUSSION

It was the purpose of this experiment to evolve an occlusal pattern which would function equally well on all three types of test foods. It is interesting to note that Pattern 9 for example (Fig. 5) performed exceptionally well on carrots but

TEST PATTERNS			FOOD			SUM OF RANKS
	UPPER	LOWER	PEANUTS	CARROTS	HAM	
PATTERN NO. 1			9	11	11	31.0
PATTERN NO. 2			7	7.5	7	21.5
PATTERN NO. 3			5	3.5	8	16.5
PATTERN NO. 4			8	10	9	27.0
PATTERN NO. 5			11	5	5.5	21.5
PATTERN NO 6			10	9	9	28.0
PATTERN NO. 7			1	1	2	4.0
PATTERN NO. 8			2	7.5	1	10.5
PATTERN NO. 9			6	2	3	11.0
PATTERN NO 10			3	3.5	5.5	12.0
PATTERN NO. 11			4	6	4	14.0

Fig. 5.—Rank order analysis of all patterns.

less well on peanuts. In an effort to demonstrate the pattern which performed to best advantage in combination with all foods, the sum of ranks was taken for each pattern. Since a rank of 1 indicated the best performance and 11 indicated the poorest, the pattern producing the smallest sum of ranks with all foods was the one which, on the average, performed to the highest degree of efficiency on all foods. Reference to Fig. 5 shows us that Pattern 7, with a total rank of 4, was the most

efficient pattern tested under these experimental conditions. Other than the outstanding performance of Pattern 7, the remaining patterns fell roughly into two groups, one group included Patterns 3 and 8-11. The patterns of this group were closely bunched in rank. The reason for this superior performance over that of the remaining patterns seemed evident. By referring to Fig. 5 and inspecting Patterns 3 and 7-11 for the presence of some special factor not present in other patterns, it can be seen that with one exception (Pattern 8) all of them presented opposing surfaces which were grooved. Inspection of the remaining Patterns 1, 2, 4, 5, and 6 showed the presence of at least one ungrooved surface in every instance except in Pattern 5.

Further inspection of the data indicated that of the most efficient group of patterns, the three which had the best composite scores on all foods, were numbers 7, 8, and 9. They possessed an upper occlusal surface marked by a longitudinal occlusal groove which ran in a mesiodistal direction. The generalization was made that with the test appliances used in this study, greatest performance resulted from using an upper occlusal surface whose cutting edges ran a longitudinal course. Substantiation of this statement was demonstrated by the improved performance of Pattern 10 over number 3. In Pattern 10, the grooves have been changed from a course perpendicular to the ridge to one of an oblique nature. When this was further changed to a longitudinal course, even without changing the opposing lower grooves as in Pattern 8, the performance was further improved.

SUMMARY

Using specially constructed appliances, 5 subjects performed a total of 962 chewing tests on peanuts, carrots, and ham to ascertain the effect on masticatory performance by 11 combinations of geometric occlusal carvings. These carvings were scored 1.0 mm. in depth and width, leaving sharp angular edges.

The results of the testing led to two conclusions regarding the action of these appliances on the test foods:

1. Performance was greater when both upper and lower occlusal surfaces were provided with cutting edges than it was when one or the other or both were without such edges.

2. Greatest performance resulted from the use of cutting edges which ran a longitudinal or a mesiodistal course on the upper occlusal surface regardless of what opposed it on the lower occlusal surface.

REFERENCES

1. Sears, Victor H.: Channel Type Posterior Tooth Forms, J.A.D.A. **15**:1112, 1928.
2. Sears, Victor H.: Factors in the Design of Special Occlusal Forms for Artificial Posterior Teeth, J.A.D.A. **24**:627, 1937.
3. Hall, Rupert E.: Full Denture Construction, J.A.D.A. **16**:1176, 1929.
4. French, Felix A.: Cusp Trauma, J.A.D.A. **11**:792, 1924.
5. Schuyler, Clyde H.: Full Denture Service as Influenced by Tooth Forms and Materials, J. Pros. Den. **1**:35, 1951.
6. Stansbery, C. J.: Balanced Occlusion in Relation to Lost Vertical Dimension, J.A.D.A. **25**:229, 1938.
7. McLean, David W.: The Physiology of Mastication, J.A.D.A. **27**:228, 1940.
8. Friedman, Samuel: An Effective Pattern of Occlusion in Complete Artificial Dentures, J. Pros. Den. **1**:402, 1951.

9. Moses, Charles H.: Studies in Articulation, J. PROS. DEN. **2**:338, 1952.
10. Sears, Victor H.: Specifications for Artificial Posterior Teeth, J. PROS. DEN. **2**:354-355, 1952.
11. Thompson, Morris J.: Masticatory Efficiency as Related to Cusp Form in Denture Prosthesis, J.A.D.A. **24**:207, 1937.
12. Manly, R. S., and Vinton, Paul: A Survey of the Chewing Ability of Denture Wearers, J. Dent. Res. **30**:314, 1951.
13. Manly, R. S., and Vinton, Paul: Factors Influencing Denture Function, J. PROS. DEN. **1**:578, 1951.
14. Payne, S. Howard: A Study of Posterior Occlusion in Duplicate Dentures, J. PROS. DEN. **1**:322, 1951.
15. Trapozzano, Vincent R., and Lazzari, John B.: An Experimental Study of the Testing of Occlusal Patterns on the Same Denture Bases, J. PROS. DEN. **2**:440, 1952.
16. Sobolik, C. F.: Observations on Occlusal Forms by an Edentulous Dentist, D. Items Interest **60**:762, 1938.
17. Hardy, I. R.: Personal communication.
18. Yurkstas, Algirdas, and Manly, R. S.: Measurements of Occlusal Contact Area Effective in Mastication, Am. J. Orthodontics **35**:186-187, 1949.
19. Yurkstas, A. A., and Manly, R. S.: Value of Different Test Foods in Estimating Masticatory Ability, J. Appl. Physiol. **3**:45-53, 1950.
20. Manly, R. S., and Braley, Louise C.: Masticatory Performance and Efficiency, J. Dent. Res. **29**:448, 1950.
21. Guilford, J. P.: Fundamental Statistics in Psychology and Education, New York, McGraw-Hill Book Co., Inc., pp. 202-205.
22. Moses, Lincoln E.: Non-Parametric Statistics for Psychological Research, Psychological Bulletin **49**:130-132, 1952.

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A LOWER UNILATERAL FREE-END PARTIAL DENTURE

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THE INCREASED AMOUNT OF good restorative dentistry being done is causing our patients to become increasingly aware of the comfort, improved function, and lack of bulk afforded by fixed bridgework. When a patient who has had this service loses the lower second or third molar which has served as the distal abutment to a three-unit bridge, he may object to the bulk of a bilateral removable partial denture which secures its stability from the opposite side of the arch by means of a lingual bar. The prosthodontist should have another solution for a patient with this condition. The solution to be described here is a combination of the ideas of many men. I have found it to be well accepted by patients and to satisfy the demands of function.

We will assume that a lower second molar has been lost after serving as the distal abutment for a three-unit bridge. The replacement I am suggesting consists of three parts.

THE ABUTMENTS

First, the two premolar abutments are splinted together with ¾ or full crowns (veneers or otherwise). These splinted crowns contain semiprecision rests: one in the mesial surface of the anterior abutment, and the other in the distal surface of the posterior abutment (Figs. 1 and 2). These custom-made precision rests are carved in the wax patterns with instruments that are specially prepared from the shanks of broken instruments. The slotted rest seats are sharpened later in the gold castings with tapered fissure burs. They have a dovetail shape, and they are made as wide and as deep as the tooth preparations will allow, thus supplying a very precise and stable seat for the denture. The lingual surfaces of the abutment castings have two undercut grooves which make definite seats for retentive arms (Fig. 3).

THE TOOTH-BORNE CASTING

The second part of the appliance is the tooth-borne portion which consists of two male semiprecision attachments that fit precisely into the seats in the abutment crowns and which are connected by a lingual bar (Fig. 4). This bar carries two infrabulge or T-arms which snap into the undercut grooves in the lingual surfaces of the crowns. These T-arms supply the required positive retention.

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The tooth-borne casting has a vertical groove or guide runner at its distal end (Fig. 5). A vertical bar projected from the third or tissue-borne part of the appliance fits into this groove, allowing vertical movement but preventing torque and lateral displacement of the denture base (Fig. 6).

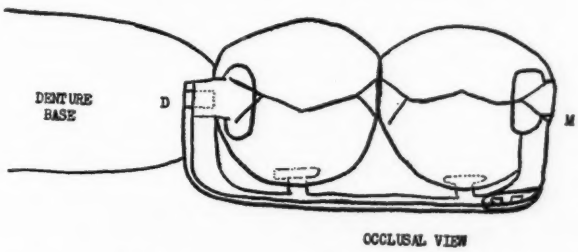

Fig. 1.—Occlusal view of the abutment castings showing the solder joints, dovetail seats, the lingual bar with infrabulge clasps, and the distal guide runner.

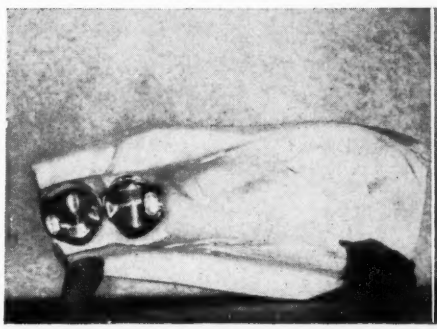

Fig. 2.

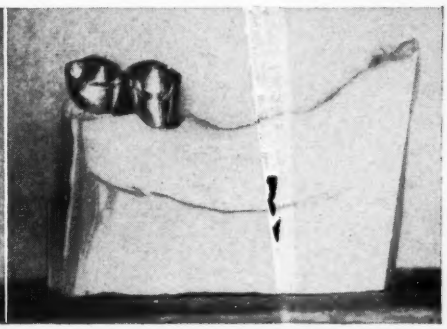

Fig. 3.

Fig. 2.—The castings in position on the cast. Note the precise seats in the mesial surface of the anterior and distal surface of the posterior abutments.

Fig. 3.—Note the undercut grooves on the lingual surface of the castings to receive the infrabulge clasps.

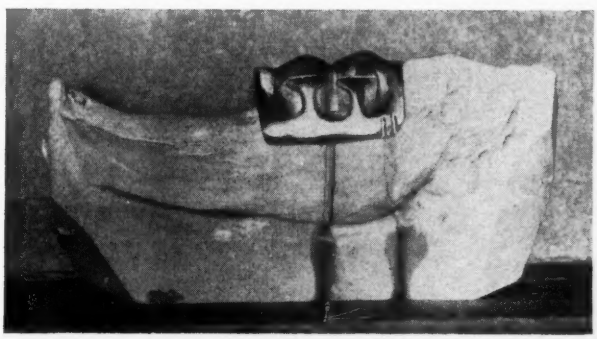

Fig. 4.—The tooth-supported section of the appliance on the cast abutments. Note the infrabulge clasps fitting into the lingual undercuts.

THE EXTENSION BASE

The third portion supplies the denture base and the missing teeth. It has a second lingual bar which fits against, and is inferior to, the tooth-supported bar

(Fig. 7). These two lingual bars are soldered together at the mesial end of the second bar at a point just below the first premolar tooth (Fig. 8). The guide runner which fits into the distal surface of the tooth-supported casting allows the denture base to be depressed toward the tissue during mastication but prevents any lateral displacement of the denture base. This split-bar type of stress breaker prevents any overloading of the distal abutment. The stress is transmitted through the bar and is concentrated at the first premolar which is supported both mesially and distally by other teeth.

Fig. 5.

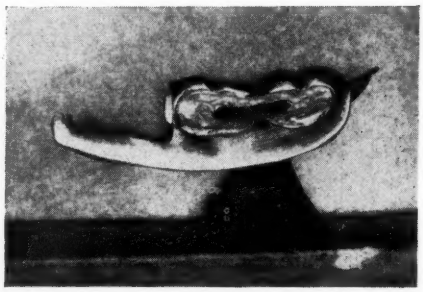

Fig. 6.

Fig. 5.—A diagram of the distal part of the tooth-borne casting. Note the guide runner which prevents lateral displacement of the cast tissue-borne section of the appliance.

Fig. 6.—The tissue-borne section. Note the guide runner which fits into the groove shown in Fig. 5.

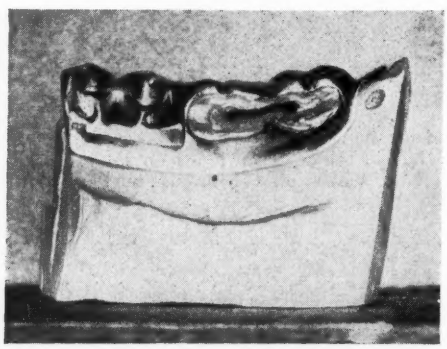

Fig. 7.—The lingual view of the assembled parts before soldering.

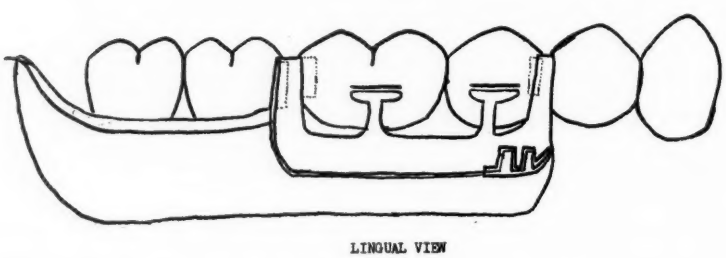

Fig. 8.—A diagram of the lingual view shown in Fig. 7.

This split-bar type of stress breaker, devised many years ago by Neurohr, has two distinct advantages over the hinge type of stress breaker. First, the stress being transmitted through the bar to the solder joint places the resultant force further forward. This reduces the distal pull on the abutment teeth more effectively than does the hinge type of stress breaker. Secondly, the hinge type of stress breaker depends upon the soft tissue to return the denture base to its rest position when the masticatory force is released, whereas this appliance springs back to position as a result of the elasticity of the metal.

TECHNIQUE OF CONSTRUCTION

The construction of this appliance is relatively simple. Hydrocolloid is used for the impressions because of its accuracy and convenience, and the chair time is minimal. Two patient visits are sufficient unless the various steps are to be checked in the mouth. A full arch lower hydrocolloid impression is made after the abutment preparations are completed. From this impression, the master cast is obtained. The crowns are fabricated and related for soldering on the master cast. The tooth-supported casting is constructed on a refractory cast made from a hydrocolloid duplication of the master cast. The tissue-supported casting is constructed in the same manner, or it may be waxed directly on the master cast against the previous castings.

The simplicity of this semiprecision rest attachment and the small amount of chair time required makes it possible to construct this kind of restoration less expensively than would be expected.

SUMMARY

A unilateral free-end partial denture with a stress-breaking design has been described. The splinting of the premolars, and the stress-breaking action of the split bar, prevents overloading of the abutment teeth. The denture fits close to the tissues and is not bulky in spite of its required rigidity (Fig. 9). The precision rests give considerable stability to the denture, and it is retained adequately by the infrabulge clasps placed into definite recesses in the lingual surfaces of the crowns on the abutment teeth. These advantages seem to offset the disadvantage of a lack of bilateral stabilization of the denture.

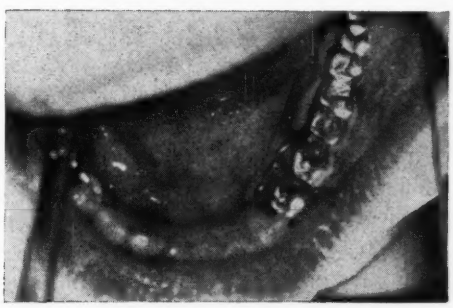

Fig. 9.—The partial denture in the patient's mouth. Note the lack of bulk and close adaptation to the soft tissues.

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OCCLUSION IN GENERAL DENTAL PRACTICE

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THE MEMBERS OF THE DENTAL profession have become increasingly aware of the significance of good occlusion. We have progressed through appreciation of occlusion in the construction of complete dentures to occlusal equilibration as an adjunct of periodontal therapy and oral rehabilitation.

The purpose of this article is to point out variations in occlusion and how they affect the different forms of dental treatment that the average dentist is called on to perform.

DIAGNOSIS

Most clocks do not show the right time. They show, at best, close approximations of the precise time. Most people do not close their jaws in centric relation. They are, at best, in an acceptable approximation of that position. The acceptability decreases with their symptoms of dysfunction and with the amount of work that the dentist plans to perform. Thus, the symptom-free patient requires less interference than the patient with temporomandibular joint pain or the one who needs immediate dentures.

These deviations from centric position of the mandible occur in the final short distance from rest position to complete closure, when the mandible is deflected from the course on which the musculature and joint mechanism would move it. This deflection is caused by interfering points which are called points of premature contact or deflective points.

Generally these points are small. Sometimes, however, they are so gross as to produce a very marked deflection, and troubles ensue (Figs. 1, 2, and 3). In such cases, patients frequently complain of pain in the anterior part of the mouth even though the deflective point is in the posterior part of the mouth. There may be a tooth or teeth that are sensitive to percussion, heat, or cold. A central incisor may be mobile or a porcelain crown may be fractured. Sometimes the patient is troubled by diffuse pains about the chin and neck. When symptoms of this sort are reported, the dentist will do well to examine the occlusion with particular attention to possible deflective points. Fig. 4 illustrates the mechanism whereby symptoms may occur at a distance from the deflective point.

It is important to realize that the individual does not actually strike the deflective point. Constant collision of that sort would be unbearable. Moyers[1] has demonstrated, through studies of the contraction of the temporal muscle, that muscles "learn" quickly of the interferences and develop new pathways which

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guide the mandible around the deflective point. This is accomplished at the expense of the fine equilibrium of the muscles involved in the maintenance of jaw position. Thus, Moyers demonstrates, through electromyography, the contracture of the muscle bands at the moment of contact with the deflective point, the subsequent contracture in advance of actual contact, and, finally, the constant state of excessive contracture. It is quite possible that this hyperactivity of certain muscle groups produces the tension about the head and neck of which some people

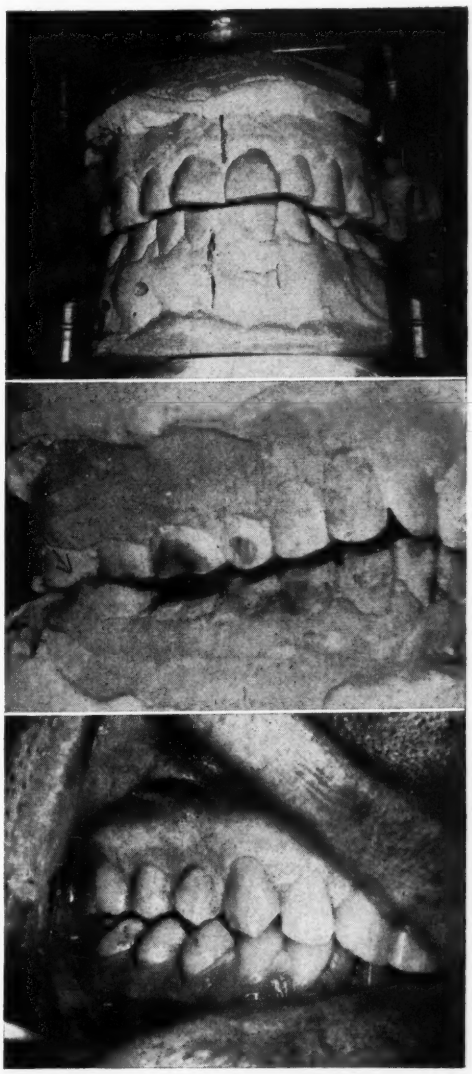

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1.—A deflection point on a bicuspid causing extreme lateral deviation of the mandible.

Fig. 2.—A deflection point on an extruded upper molar causing protrusion of the mandible. Extensive restorative work had been performed at this protruded position.

Fig. 3.—An anterior displacement of the mandible was caused by a deflection point on a bicuspid. The patient complained of pains in the anterior teeth radiating down through the chin and neck.

complain. However, Schwartz[2] considers the occlusal factor only contributory in these latter cases. He believes that the factor of stress, with attendant muscular tension, is the predisposing cause. It is certainly clear that traumatic incidents such as extraction, exposure to cold, or excessive stretches can induce muscular spasms of varying intensity and consequent malocclusion. The psychogenic factors are far less evident and pose a difficult problem to the dentist in his diagnosis.

Fig. 4.—This very common situation occurs after the loss of a lower third molar. The upper molar extrudes, and the lower molar is deflected in closure. The mandible moves forward to accommodate for this interference with an attendant impact on the anterior teeth. A similar situation is frequently seen on the mesial planes of the upper first bicuspid.

RESTORATIONS

The dentist must be able not only to recognize these variations from centric position, but he must avoid producing them himself. Our fillings and inlays may have high points, or our contact points may be too tight, causing deflection points on adjacent teeth. Here the dentist may be misled by finding no carbon paper marks on his restoration. The patient adapts to the malocclusion very rapidly, even within the adjustment time of a single sitting. He may mention that the filling was high, "but it wore down." It did no such thing. The patient developed a new neuromuscular response to avoid striking the point, and so the approximation of centric relation suffered further impairment.

What applies to operative dentistry is more manifest in crown and bridgework. Here, since the restoration is greater, the possibility of deflection points and the degree of interference is increased.

In extensive rehabilitation, the difficulties multiply. It is essential to determine that the mandible is in centric relation before the restorations are made. Fig. 2 shows the casts of the teeth of a woman who had extensive inlay, crown and bridgework made with the mandible in an eccentric position. An anterior solder joint had cracked already under the strain.

In constructing immediate complete dentures one must avoid the temptation to accept the habitual occlusion of the patient. Figs. 5 and 6 show a patient for whom an immediate complete upper denture was constructed. The lower left cuspid was locked labial to the upper lateral incisor. When this condition was freed by heavy grinding and the elimination of all deflective points, the mandible moved back 2 mm. Had the dentures been constructed by articulating the casts by hand or by extracting posterior teeth and using occlusion rims without grinding the teeth, a very poor occlusion could have resulted.

The importance of occlusion in periodontal treatment has become too well accepted to require further mention here.

Following orthodontic treatment, there may well be deflection points that require correction. This is the obligation of the orthodontist, however, unless it is understood in advance that the general dentist will terminate the treatment with such correction.

Fig. 5.

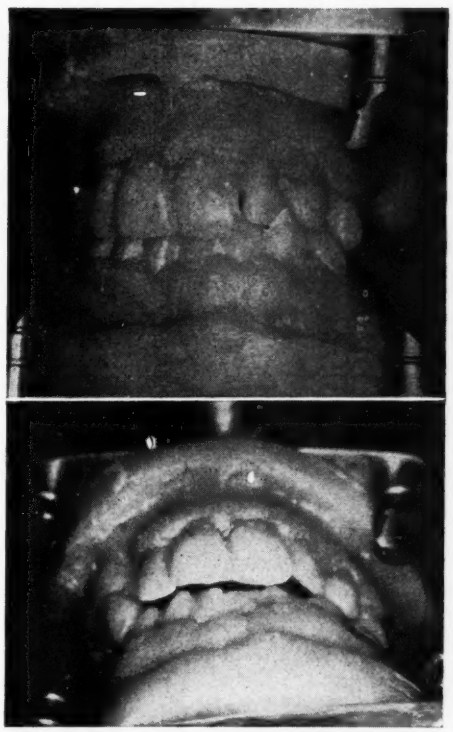

Fig. 6.

Fig. 5.—The mandible locked in position by the lower cuspid in labial version.

Fig. 6.—The mandible has moved to the distal into centric position after grinding the cuspid and other deflection points. An immediate upper denture was constructed in this position.

INTERFERENCES IN LATERAL MOVEMENTS OF THE MANDIBLE

The most significant interferences occur on the balancing (nonworking) side. It has been more usual to pay attention to interferences on the working side. The two most common causes of balancing side interference are (1) the loss of the mandibular first molar with the subsequent mesial and lingual tilting of the remaining molars and the extrusion of the upper molar, and (2) the extraction of the upper third molar, followed by the overeruption of the lower third molar. As the mandible approaches the completion of the chewing cycle, with the teeth on the working side still apart, the teeth on the balancing side are already in contact (Fig. 7). A severe strain is placed on these teeth, with sequelae such as

pain, loosening, and pocket formation. It is not a coincidence that when there is mobility of teeth, it occurs most commonly on the second and third molars, particularly when the cusps are long. If the teeth remain firm, their cusps may fracture, or they may act as a fulcrum and transmit the strain to the temporomandibular joint. This is a frequent cause of joint pain and injury (Figs. 8 and 9).

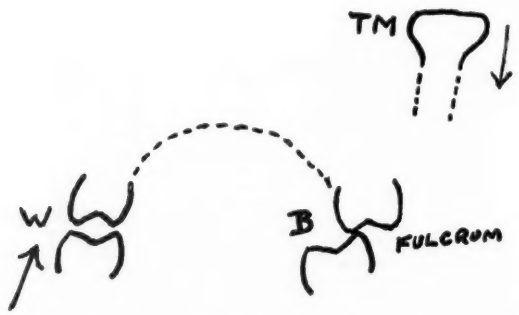

Fig. 7.—*W,* Working side. *B,* Balancing side. *TM,* Temporomandibular joint. With the teeth closing through the food on the working side, there is an interfering contact on the balancing side. These teeth either become loose or act as a fulcrum and cause strain on the temporomandibular joint.

Fig. 8.

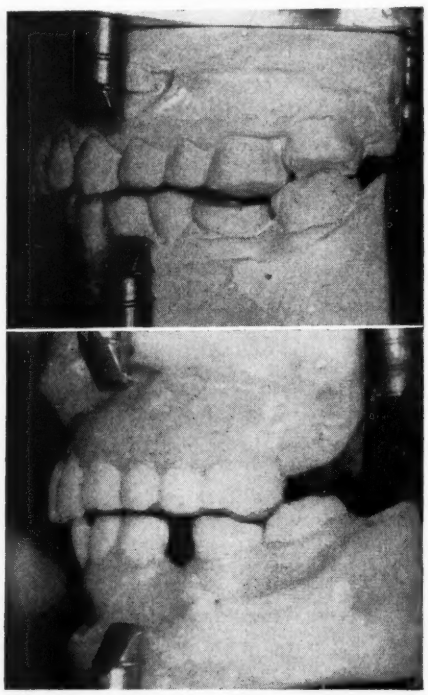

Fig. 9.

Fig. 8.—The continuing eruption of the upper first molar after attrition of a lower plastic crown. Balancing side interference with mobility, pocket formation, and pain resulted.

Fig. 9.—Balancing side interference on an overerupted molar. Severe temporomandibular pain was relieved by the extraction of the lower second molar.

The dentist must be careful not to reproduce balancing side interferences in his dentures and bridgework (Fig. 10). The immobilization of these teeth in fixed bridgework will make the interference apparent to the patient, and the sequelae of irritation, pain, cheek-biting, or joint pain will occur. He must not produce the situation through inadequate occlusal height in his restorations. For example, an excessively deep fossa in a filling in a lower molar can cause the downgrowth of the lingual cusp of the upper molar, with consequent interference on the balancing side. These points are difficult to observe visually. A particularly good way to locate them is to attempt to withdraw a strip of paper, cloth, or cellophane from the balancing side while the patient moves his jaw toward the working side. The method of correction is excellently described by Schuyler.[3]

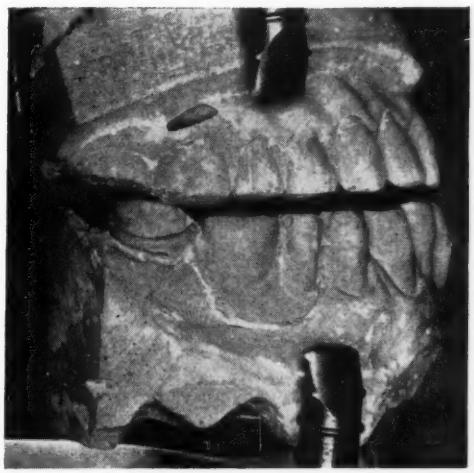

Fig. 10.—An upper complete denture was unseated by balancing side interference of a lingually tilted natural lower molar. Denture stability was increased by grinding the buccal cusp of the lower molar.

Interferences on the working side seem less likely to lead to such sequelae. In general, such interferences occur on the cuspids which are particularly well able to resist the stress. Where the cuspids show evidence of weakening, it is obviously of benefit to distribute the load over as many teeth as possible. The dentist should be on guard against producing interfering planes in his restorations with the consequences of overloading.

By the same token, protrusive is a less actively used position, but here, too, it is often desirable to distribute the stress over a few teeth.

BRUXISM

Grinding habits, called bruxism, will magnify any of the damages of occlusal inequalities. It has been suggested that deflection points are a stimulus to these oral habits. Certainly a high point on an inlay will elicit a persistent semivoluntary grinding or clenching. Nevertheless, it would seem that the cause for such habits lies elsewhere.

TECHNIQUES

It is not my intent to discuss techniques for locating deflection points and for grinding teeth. Schuyler[3] and Shore[4] have covered this exhaustively. Shpuntoff and Shpuntoff[5] have demonstrated that the patient should be erect when tests are made for locating deflective contacts. The patient is instructed to chop rapidly into softened wax covering the entire arch. Aluwax cloth forms are excellent for the purpose. As he continues to chop into the wax, the first deflective point appears as a minute hole in the wax. The tooth is marked with articulating paper or typewriter ribbon, and the colored mark corresponding to the hole is ground. The hole in the wax form is filled in, the wax is softened, and the process is repeated. For more delicate determination, or for locating deflective points which are on mobile teeth, the 30-gauge casting wax as used by Shanahan[6] is most suitable. This is particularly useful for discovering high points on new inlays or crowns. Carbon paper alone is not adequate because it leaves too many marks. Simply following the patient's guidance and the carbon marks frequently leads to restorations which have been ground out of occlusion.

SUMMARY

The dentist must be aware of the significance of occlusal inequalities in diagnosis and treatment planning. He must avoid producing interfering points in his restorations. Attention must be paid to centric position and to lateral movements, particularly on the balancing side.

REFERENCES

1. Moyers, R. E.: Some Physiologic Considerations of Centric and Other Jaw Relations, J. Pros. Den. **6**:183-194, 1956.
2. Schwartz, L. L.: Pain Associated With the Temporomandibular Joint, J.A.D.A. **51**:394-397, 1955.
3. Schuyler, C. H.: Correction of Occlusal Disharmony of the Natural Dentition, New York D. J. **13**:455, 1947.
4. Shore, N. A.: Equilibration of the Occlusion of Natural Dentition, J.A.D.A. **44**:414-427, 1952.
5. Shpuntoff, Harry, and Shpuntoff, William: A Study of Physiologic Rest Position and Centric Position by Electromyography, J. Pros. Den. **6**:621-628, 1956.
6. Shanahan, Thomas E. J.: Physiologic Vertical Dimension and Centric Relation, J. Pros. Den. **6**:741-747, 1956.

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DIAGNOSIS AND TREATMENT PLANNING

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IT IS THE RESPONSIBILITY of the dental profession to maintain the patient's dentition over a maximum life span. This necessitates an analysis of the complete masticating organ, rather than simple reparative service to individual teeth. Adequate study must be made during the diagnosis to determine the causative factors of destruction in the oral cavity prior to subsequent treatment planning and treatment.

It is necessary to check with our allied profession for the organic and systemic conditions of patients, with special emphasis on the endocrine system. Imbalance in the function of the ductless glands has predisposed many patients to poor dental health. Dental roentgenographs can aid in disclosing thyroid static conditions, and the medical profession is grateful for our dental disclosures.

DIET

The profession has rendered a tremendous service to the public through its research in nutrition. Almost without exception, dentists educate the public in the value of a high protein diet, the tremendous dental destruction caused by an excessive carbohydrate diet, and the need for a mineral supplement in diets for people in many areas of our country (Fig. 1).

Generally speaking, the dental profession has allowed the public to dictate dental care, with the result that menial reparative service has been the common procedure. The public should have been requesting the profession to diagnose the oral conditions so that the profession would render a complete dental service. Unfortunately, it has been economically advantageous to place simple and quickly placed restorations and to fill the spaces caused by the premature loss of teeth with removable appliances that are prefabricated by commercial laboratories and which have no purpose as a functioning unit except as space retainers.

It has been shown by postgraduate departments of dental schools, study club units, and particularly by the gnathological societies that balanced occlusion, with special emphasis on equalization of maxillomandibular stress throughout centric and eccentric functional occlusions of the jaws, can afford indefinite life to the dental organ. This is true even though the supporting tissues have become weakened due to imbalance in the functioning of the opposing teeth.

TREATMENT PLANNING

Proper diagnosis and treatment planning should include a complete set of diagnostic roentgenograms, an accurate set of study casts mounted in an adjustable

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articulating instrument on the patient's axis orbital plane, as well as the pertinent medical history of the patient. When correct functional jaw positions are recorded and transferred to the instrument, the patient can be shown as well as told what is taking place throughout the functional mechanism of the jaws. It then becomes simple to disclose the causative factors of destruction to the teeth and their supporting structures and to plan to correct and alleviate this wrecking process. Temporomandibular movements, particularly the condyle path and lateral shift of the

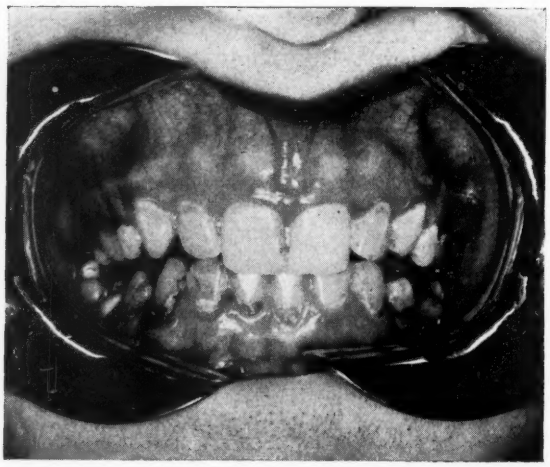


Fig 1.—Rampant caries caused by a high carbohydrate diet.

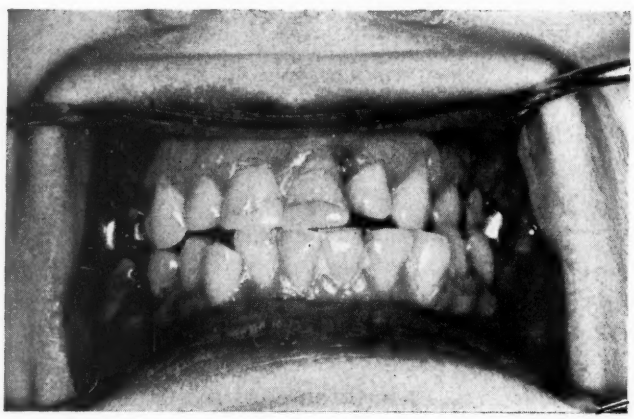


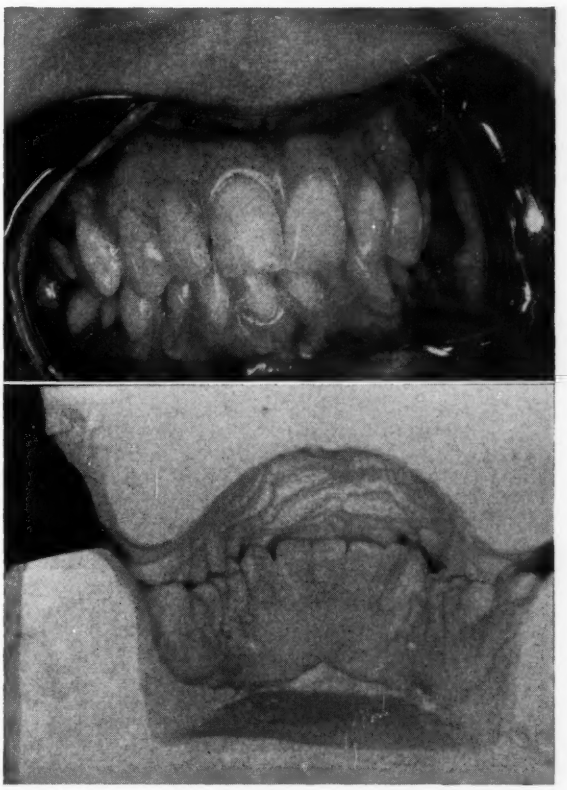
Fig. 2.—Destructive alveolar trauma and tooth movement caused by night grinding of the teeth.

condyle, become apparent. An excessive vertical overlap with upper and lower anterior teeth locked is more readily analyzed for correct treatment planning. Positional relations of the jaws can be simulated to show the premature contacts of inclined planes of individual teeth, excessive attrition in eccentric occlusions, and tooth contact during bruxism (Fig. 2).

GROWTH IN LOWER ARCH

If the lower anterior teeth are on a higher plane than the lower posterior teeth, it is a disturbing condition (Fig. 3). A destructive process is unavoidable with advancing age or inadequate vitality of the supporting tissues. In some instances, an increase in vertical height of the lower posterior teeth can be induced by placing an orthodontic splint in the palate with occlusal contact available only in the anterior area (Fig. 4). The best results are obtained by wearing such

A.



B.

Fig. 3.—*A*, A locked occlusion of the upper and lower anterior teeth. *B*, The lower anterior teeth are on a higher plane than the lower posterior teeth.

an appliance constantly over a limited period of time. These patients must be followed carefully to establish the correct intercuspation of the opposing teeth in centric occlusion when the mandible is in its centric position (Fig. 5).

SPLINTING TEETH

Teeth loosened by trauma will often tighten if they are splinted together with their approximating members. Experience has shown that complete fixation is not always the correct answer. Splinting by means of precision rests can induce a more healthy supporting tissue in some cases. Perhaps the fact that the jaws

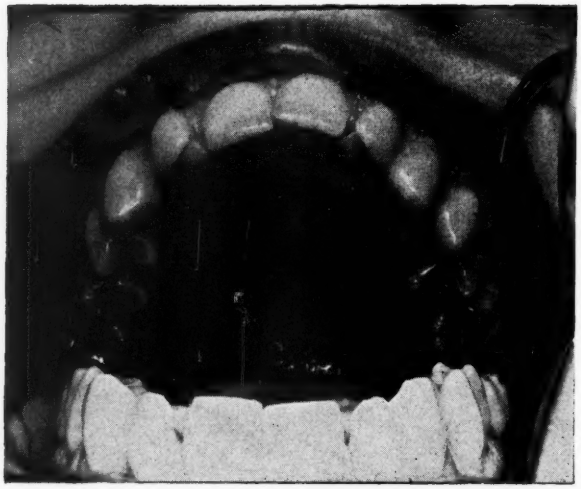
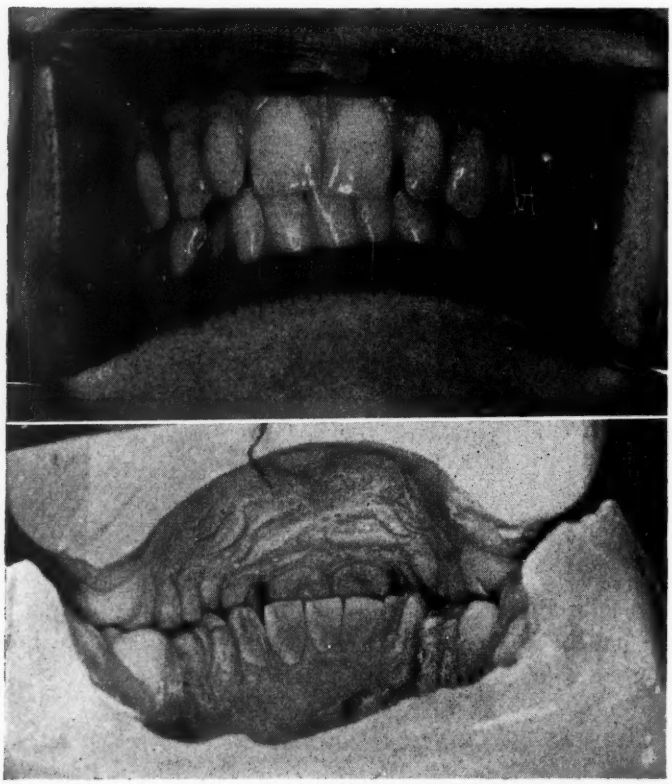


Fig. 4.—A palatal splint providing occlusal contact only in the anterior region.

A.



B.

Fig 5.—The further eruption of the posterior teeth obtained by the constant wearing of the palatal splint for a period of six months. *A*, Anterior view; *B*, note the reduced vertical overlap of the anterior teeth.

are arched in the form of an unorthodox curve, with each individual tooth tolerating stress to best advantage in a slightly different phase of movement, makes it mandatory that some freedom of movement be allowed to prevent unfavorable thrusts in certain positions. In such cases, precision rests allow a limited freedom of movement, yet they call upon the approximating tooth to share an excessive downward thrust into the bony socket.

HARMONIOUS CURVE OF SPEE AND OCCLUSAL PLANE

The loss of one or more teeth without immediate replacement has been a frequent occurrence, with resultant loss of contact between approximating teeth within the arch and an elongation of the teeth in the opposing arch. Treatment planning in such instances is complicated by a lack of harmony of the curve of Spee and the occlusal plane with the path of movement of the temporomandibular joint and the cusp rise that exists in the anterior segments of the arches. The path of movement of the condyle is fixed and must be followed, whereas the cusp rise in the anterior segments of the arches can be reconstructed by the dentist (within operating limits) to aid in establishing a harmonious intercuspation of the posterior teeth. This problem must be carefully planned for correct reconstructive procedure before reconstructive work is started.

A. *B.*

Fig. 6.—The teeth of the study casts are waxed to predetermine the cusp contour necessary to produce balanced functional occlusion. *A*, Right side; *B*, left side.

A wise procedure is to have the study casts mounted in an adjustable articulator on the patient's axis orbital plane, with correct condyle settings for both centric and eccentric functional positional movements. Then with inlay wax, build the teeth of the study casts to the contour that will produce balanced occlusion throughout the functioning excursions. The dentist can then determine the teeth that will need a decrease or an increase in vertical dimension and the cusp rise in the anterior segments necessary to create a correct curve of Spee and plane of occlusion for the posterior quadrants (Fig. 6).

MUCOSTATIC GOLD BASES

Mucostatic metal bases have proved their merit in distal extension removable partial dentures and where the span of replacements is excessive for fixed partial dentures. Numerous experiments have proved that soft tissue can be rendered solid under a mucostatic base. The success of this type of replacement depends, to a great extent, upon the alignment and temporary fixation of the base with the attachments directly in the mouth. Quick-setting plastic is an excellent material for this purpose. It then becomes simple to create a permanent fixation by spot welding. This type of replacement enables the dentist to make posterior occlusal segment gold castings that can be attached to the base and exhibit adequate cusp contour for balanced functional occlusion. Such bases, properly constructed and aligned with the retainer units, can reduce tissue displacement to a minimum, thus preventing torsional stress on the retaining abutment teeth.

SUMMARY

It is the responsibility of the profession to maintain the oral cavity in a healthy functional condition for a maximum length of time. Diet is and always will be of such importance that it cannot be overlooked. A careful analysis of contributing destructive factors must be made. This includes systemic and organic imbalance, with particular emphasis on the endocrine system. Accurate study casts mounted in an adjustable articulating instrument on the patient's axis orbital plane, with both condyle path and condyle shift movements set to duplicate the existing movements of the patient's mandible, are equally as important as are diagnostic roentgenograms. Before reconstructive work is started, the individual teeth of the study casts should be waxed to the contour necessary to produce a balanced distribution of stress over the upper and lower teeth throughout the functional centric and eccentric movements.

Dental service must be a complete evaluation of health factors and balanced functional occlusion, rather than a reparative service to individual teeth, if the life expectancy of the masticatory organ is to reach maximum life span.

Many weakened individual teeth can be strengthened and placed back into function if they are splinted into fixed or semifixed contact with their approximating members. Experience has proved that careful alignment, directly in the mouth, of accurately fitting mucostatic bases with retainer units will reduce displacement of the bases and retainer units, thereby eliminating excessive torsional strain.

It is not unreasonable to think that the life expectancy of the natural dental organ can survive over the complete life span of the individual, if a reasonable state of good health is maintained, if mouth hygiene habits are instituted and supervised, and if functional maxillomandibular stress can be balanced properly and distributed throughout the entire dentition.

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DEGENERATIVE JOINT DISEASE OF THE TEMPOROMANDIBULAR JOINT

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DEGENERATIVE JOINT DISEASE AS defined by Abrams[1] is a "chronic arthropathy characterized pathologically by degeneration and hypertrophy of cartilage and bone, and clinically by pain, which occurs generally on use and is relieved by rest. It occurs chiefly in older individuals, usually in weight-bearing joints or the terminal interphalangeal finger joints. In general, it is unaccompanied by systemic manifestations."

There are a number of other terms which are also applied to this disease: osteoarthritis, hypertrophic arthritis, degenerative arthritis, arthritis deformans or deforming arthritis, and senescent arthritis. The changes in this disease are degenerative in nature, and so the use of the term "arthritis" has recently been looked upon with some disfavor. The American Rheumatism Association has accepted "degenerative joint disease" as the preferable descriptive term.

HISTORY

Abrams[1] quotes reports of the pathologic changes in the skeletons of dinosaurs that lived over 200 million years ago, exostoses of the femur in the "Java Man" living about a half million years ago, and characteristic spinal changes in the Neanderthal man who lived about 40,000 B.C. Ruffer[2] found evidences of pathology in the temporomandibular joints of early skulls of modern man. Degenerative joint disease has been seen in Egyptian mummies and prehistoric American Indian remains.[1] The surgeon of the Old Kingdom in Egypt, 3,000 B.C., had a sound working knowledge of the anatomy of the mandible and its articulations, and the Edwin Smith Papyrus,[3] the earliest known surgical text, reports a "dislocation of the mandible" with a diagnosis and method of reduction that is still in use today.

Cooper has been quoted[4] for calling attention, in 1842, to a condition of the temporomandibular joint characterized by snapping, and, in 1887, Annandale called attention to opening into the joint, repositioning the articular disk, and suturing it with catgut to the outer side of the joint. Lang is named[4] as the surgeon who, in 1909, introduced disk extirpation.

The role of the dental apparatus in temporomandibular joint disturbances was first brought out by Prentiss[5] and Summa.[6] Costen[7-11] and Goodfriend[12-16] initiated the intense modern interest of the dental profession in the pathologic disturbances of the temporomandibular joint.

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ANATOMY

Despite the many years of study, we still have much to learn about the anatomy and actions of the temporomandibular joint. Sicher,[17-20] Shapiro,[21, 22] and Robinson[23] have made notable contributions to our knowledge of the anatomy and actions of this joint.

The mandible is unique in that it terminates in identical articulations. The temporomandibular joint is a ginglymo-arthrodial joint, which is said[24] to be the only joint in the body that can be dislocated without rupture of its capsule. It is the articulation of the condyle with the articular disk, the articular fossa, and the articular tubercle. The basic anatomy is so well known that we can leave its description to the standard textbooks of anatomy. There are certain anatomic facts, however, that warrant special notice because of the implications involved.

There is evidently no pressure on the bone separating the articular fossa from the middle cranial fossa. This is indicated by the facts that the bone is very thin, there is no cancellous bone, and it is lined with simple periosteum; whereas bone under pressure has a layer of cancellous bone and is covered with dense fibrous connective tissue containing cartilage cells. Amer,[25] and Shapiro and Truex,[21] found great variations in the shape, size, degree of wear, and position of the condyles. There were even marked variations between the two condyles in the same individual.

THE ARTICULAR DISK

The articular disk or meniscus is composed of a specialized connective tissue, not the fibrocartilage usually ascribed to it. This indicates that the lesions of the disk can be repaired if the causes of the pathologic process are removed. This is of the greatest importance both in treatment and prognosis. Landa[26] states that in the course of examining 1,000 disks of human cadavers in the Department of Anatomy, New York University College of Dentistry, only one disk perforation was found. Shapiro and Truex[21] were unable to find a single perforated disk in over 100 human cadaver dissections.

The articular disk is fused medially, anteriorly, and laterally to the articular capsule. Posteriorly, however, it is connected to the capsule by loose, highly vascular connective tissue and is supplied by nerves from branches of the auriculotemporal nerve. The disk and its attachments serve to divide the joint into the upper and lower joint cavities. These are not true body cavities. The synovial membranes, which line these cavities, form small folds and villa and are very richly supplied with blood vessels, nerves, and lymphatics.

THE LIGAMENTS

The caspular ligament is a thin, loose, fibrous sac with the temporomandibular ligament on its lateral side. The stylomandibular and sphenomandibular ligaments are fascial in origin. It is most important to recognize that the ligaments merely limit the movements of the elements of the joint. It is the muscles that actually maintain the joint elements in their positions.

THE NERVES

The auriculotemporal nerve crosses the neck of the condyle so that it cannot be compressed by a displaced condyle. It supplies the skin of the temporal region, part of the outer ear, the parotid gland, and the articular capsule. Thus, an injury to the capsule could stimulate this nerve and produce pain referred to the other areas it supplies.

The extratympanic part of the chorda tympani nerve lies in the depth of the petrotympanic fissure and is separated medially from the articular capsule by the angular spine of the sphenoid bone, but at the point where it emerges through the fissure, it is directly related to the capsule posteriorly. It is composed of taste fibers and parasympathetic preganglionary fibers of a secretory nature. It does not seem possible for a displaced condyle to affect this nerve, and even were this possible, there are no specialized fibers for receiving or conducting pain.

Posterior displacement of the condyle due to an overclosure of the mandible can neither compress the eustachian tube nor interfere with the opening action of the tensor palati muscle. The elevation of the angular spine of the sphenoid bone medially will not permit the condyle of the opposite side to move beyond the postglenoid tubercle. Only if the postglenoid process were destroyed could the condyle impact and erode the tympanic plate. Sicher[18] and Shapiro[22] have failed to find any significant erosions of the tympanic plate in the cadavers they have examined. Sicher[27] concludes: "Even if all defects in the lateral part of the tympanic plate are considered as caused by articular changes, this condition is extremely rare, is restricted to the oldest age group, and cannot in any way be related to disturbances of hearing."

JOINT ACTION

The actions of the temporomandibular joint are so complicated that the concentrated research of the past twenty years has only begun to reveal them in all their complexity. Mastication represents only a relatively small part of the work the joint performs every day. It is actively involved, for example, in swallowing, and this is estimated to occur every 60 to 90 seconds. It is the neuromuscular apparatus that governs all movements, and the perfection of timing essential to all normal actions is an amazing phenomenon.

The mandibular muscles function as a unit, and in mandibular movements they are all involved—internal and external pterygoids, temporal, masseter, digastric, geniohyoid, and mylohyoid. When one muscle contracts, the opposing muscle must relax, and this must be a smooth, well-related, and split-second action. For example, the upper head of the external pterygoid muscle maintains the balance between the articular disk and the joint, while the lower head moves the condyle forward and downward. The digastric and geniohyoid muscles pull the chin downward and backward. At the same time, the elevator muscles must gradually relax to maintain stability and to provide a smooth movement. All muscular activity is controlled by regulating neural reflexes which originate in proprioceptive nerve endings in the muscles themselves, the articular capsule, and in the periodontal ligaments of the teeth.

Muscles contract in two ways: (1) In isotonic contraction, the muscle tenses and shortens, and (2) in isometric contraction the muscle tenses but maintains its length. Thus, in isotonic contractions the muscle acts as a mover, and in isometric contraction it acts as a stabilizer. Electromyography[41-43] has opened a new way to study the actions of the mandibular musculature and certainly has much to offer in the future.

Basically, there are two types of joint movement: (1) ginglymoid or hinge, which takes place in the inferior synovial cavity, the smaller of the two synovial cavities, and (2) arthrodial or gliding which takes place in the superior synovial cavity, the larger of the two. The articular disk is tightly connected to the medial and lateral poles of the condyle by the articular capsule so that it follows the condyle in all the condylar movements.

It would seem that, in normal masticatory movements, the forward gliding action is negligible because the actual mandibular opening is limited. Forceful closure, as in heavy mastication, starts from a limited opening with the condyle and disk in a retruded position in the articular fossa.

Robinson[28] offers impressive proof that the temporomandibular joint is not meant to bear heavy stress. He conceives of the action as a reflex-controlled non-lever action, and, to quote him,[28] "The muscles of mastication are so placed that the resultant force of their actions can be borne by the teeth, the joint being left free from traumatizing stress."

Roentgen motion pictures of the temporomandibular joint have now been made possible by the use of image intensification.[29] This gives us a means of studying the joint actions in health and disease such as we have never had before. The opportunities this method offers are most exciting to the imagination and would seem to be almost unlimited in their scope. Certainly, we can look forward to an understanding and knowledge of joint movements far beyond anything we have ever had.

INCIDENCE

Abrams,[30] speaking from the broad medical point of view, states that degenerative joint disease is present universally after 40 years of age but that only 5 per cent present clinical symptoms. He quotes Bennett, Waine, and Bauer[30] who found that the changes of degenerative joint disease appear in the second decade of life and increase in frequency and severity with age.

Bauerle and Archer[31] investigated the incidence of a condition they termed subluxation of the temporomandibular joint. They diagnosed this condition by the symptoms of pain and clicking or snapping sounds in the joint. How many of these patients really suffered from degenerative joint disease, it is impossible to say. Out of 1,200 unselected individuals, 40 per cent had what the authors termed subluxation. Of these cases, 50 per cent of the edentulous patients wearing dentures had this condition. It occurred as often in men as in women, and the incidence increased with age.

Bowman[32] found temporomandibular joint arthrosis in one-third of the 1,350 adults examined. Markowitz and Gerry[33, 34] found 28 per cent of 700 adults had temporomandibular joint disturbances.

The absence of uniform diagnostic standards and definitions makes it impossible to evaluate these figures properly. It can be concluded, however, that temporomandibular disturbances are widespread.

ETIOLOGY

Degenerative joint disease is related to the physiologic process of aging. Abrams[85] summarizes the etiologic factors from the medical point of view as follows:

"1. Practically all students of arthritis acknowledge the fact that increased stresses and strains on joints (chronic irritation) comprise the most important causative factors in the production of degenerative joint disease.

"2. Not all cases can be attributed to this cause. Theories have been advanced concerning the role of aseptic necrosis, metabolic disorders, focal and systemic infection, vascular changes, endocrine disturbances, and heredity. Most of these theories have been discarded. However, heredity appears to play a part. The role of endocrine disturbances has not been conclusively determined but probably is of minor importance."

Of great interest to the dentist are two reports Abrams quotes[80]:

1. Parker and his associates: "Degenerative arthritis is a process associated with the aging of the tissues of joints, aggravated by strain, hemorrhage, trauma, and static deformities, the end results depending on a summation of these factors."
2. Bauer and Bennett: "Degenerative arthritis is the result of the wear and tear of increasing age and repeated trauma which might be caused in a variety of ways."

Degenerative joint disease of the temporomandibular joint has no simple etiologic factor, but a combination embracing:

1. Microtrauma, with prematurities and other forms of traumatic occlusion.
2. Overclosure of the mandible in which the condyle suffers a posterior displacement, impinging on the loose connective tissue which connects the posterior border of the articular disk to the articular capsule, eventually causing a degeneration of this tissue and a breakdown of the entire articulation.
3. Hypertension of the mandibular musculature, trismus, and bruxism. Muscular spasms can throw enough pressure of themselves on the joint to do damage. Once the muscles are in a state of contraction, there is a strong tendency to pull the articular disk forward, and the condyle backward, to produce damage by impinging on the loose connective tissue attaching the posterior border of the articular disk to the articular capsule. Muscular spasms may be produced by emotional factors, and both traumatic occlusion and overclosure of the mandible seem sooner or later to be capable of throwing the mandibular musculature into a spastic state.
4. Age. Degenerative joint disease develops with increasing age, starting in the second decade of life, but it may be symptomless. Bauer[86] examined 5 patients clinically before death and then did a microscopic examination of the temporomandibular joint post mortem. He found that the joint accommodated to pathologic function so well that even where there was almost a complete destruction of the disk there were no marked local or reflex symptoms.
5. Heredity, a factor whose importance has yet to be determined.

PATHOLOGY

Degenerative changes occur in the hyaline articular cartilage from wear and tear, microtrauma, and attrition. Proliferation, spurs, lipping, osteophytes, and deformity of the condyle occur. The synovial villa hypertrophy. The changes continue until the articular covering is gone. Marginal outgrowth show signs of degeneration. The exact mechanism by which joint function contributes to degenerative joint disease is not known. Abrams,[37] speaking about this disease in joints throughout the body, makes a statement which must sound very familiar to the dentist: "These fibrillated, roughened cartilages produce a degree of friction as they slide against one another (which may be palpable and audible)."

SYMPTOMATOLOGY

Abrams,[30] again speaking generally, states that the chief symptom of degenerative joint disease is pain on motion which gets worse on prolonged activity. The pain is usually an aching type, rarely intense, and is relieved by rest. Stiffness is common, particularly after prolonged rest.

In 1918, Prentiss[5] and Summa[6] observed that loss of teeth without replacement and malocclusion cause damage to the joint. Prentiss also reported lesions in the joint tissues revealed by his dissections. Wright[38] claimed that he found deafness due to malpositions of the condyles.

Costen[7] gave the classic description of the symptoms of temporomandibular joint disturbances, and it has become known as Costen's syndrome. This is an all-inclusive collection of symptoms and a most debatable one as well. From both a scientific as well as clinical point of view, it would be best to replace "Costen's syndrome" with the diagnostic term, degenerative joint disease of the temporomandibular joint. In another article,[39] the author offers a classification of the symptoms which can be used to advantage for the purposes of classification and further study:

"1. Those symptoms that have a debatable connection with temporomandibular joint disturbances—loss of hearing, tinnitus aurium, aural vertigo, headaches typical of sinus disease, neuralgias either trigeminal or strongly similar. No anatomic or physiologic basis has been found for these symptoms.

"2. Those symptoms that have a proved connection with temporomandibular joint disturbances—local and referred pain, clicking, swelling over the joint, muscular pain."

Cases of Menière's disease have been reported[16] that responded favorably to dental treatment exclusively. Cases of trigeminal and auriculotemporal neuralgias are also said[16, 40] to be cured by dental treatment. There are many investigators[41–48] who agree with Costen's syndrome and claim cures for these symptoms which I shall refer to hereafter as the "debatable symptoms." These symptoms are usually explained by condylar pressure caused by the posterior displacement of the condyle due to a loss of vertical dimension. In discussing the anatomy of the joint, we pointed out that these theories of pressure on the chorda tympani and auriculotemporal nerves, the eustachian tube, and the outer and middle ear are

fallacious. Sicher,[38] Shapiro and Truex,[21] Landa,[26] and Schreiber[44] are representative of the growing group which insists that these "debatable symptoms" should not be ascribed to temporomandibular joint derangements. However, in view of all these confirmative reports, we cannot dismiss them entirely. We should, however, insist upon more scientific proof before we accept them. Research in this field is definitely indicated.

The symptoms we can definitely ascribe to degenerative joint disease of the temporomandibular joint can be grouped as follows:

1. Pain in the joint, swelling and tenderness over the joint.
2. Pain in the adjacent regions, either referred pain or the typical pain of muscular spasms. According to Sicher,[45] the pain is localized as follows:
    1. Temporal muscle to the temple or region of the ear.
    2. Masseter muscle to the cheek.
    3. Pterygoid muscle to the throat.
    4. Digastric and geniohyoid muscles to the tongue.
3. Stiffness, both in the joint and in the mandibular muscles, being more marked after a period of disuse.
4. Clicking, snapping, or grating sounds in the joint.

The pain is a dull, constant type of pain which is very persistent. Schwartz[46] found the pain in a series of 500 patients to be almost exclusively unilateral.

ROENTGENOGRAPHY

Anatomic considerations make the temporomandibular joint a most difficult area to visualize roentgenographically. Many techniques have been tried, those most commonly used today being the cranial-oblique. Three of the latest techniques are so radically different that they warrant special mention. Arthrography shows the two synovial cavities by injecting into them a contrast medium, but aside from the information it gives about the synovial cavities, it gives practically no information about the rest of the joint. Cephalometric laminagraphy has been advocated, particularly by Ricketts.[47-50] This technique utilizes a mechanical focusing device to obtain a roentgenographic visualization of a prescribed plane with a width of cut approximately 0.5 to 0.75 cm. It involves the synchronous movement in opposite directions of the x-ray tube and the film cassette while the exposure is being made. The latest and certainly the most promising technique is that of cinefluorography with image intensification.[29] By electronic means, the image on a fluorescent screen is intensified 1,000 times in brightness, which permits lower levels of radiation to the patient. It thus becomes possible and safe to secure roentgen motion pictures of the temporomandibular joint, and these are made with sound accompaniment. This technique is so new that no evaluation is possible except to say that it would seem to offer a great potentiality.

Some investigators[40, 47-53] claim to be able to make a very exact and scientific diagnosis of temporomandibular joint roentgenographs. Unfortunately, there is no generalized support for their claims. Schreiber[44] sectioned a cadaver head, and, using one-half, took 12 roentgenographs of the joint. Even with no superimposi-

tion of the opposite condyle and associated structures, he failed to obtain a single accurate reproduction of the condyle. Junemann[54] studied a large number of roentgenographs of the joints of patients who showed clinical evidence of disease. He could find no evidence in the roentgenographs of irregularities, destruction of bone, or other abnormalities of any of the bony structures.

Condyles vary widely in size, shape, positions, and inclination. Lateral plates are made with the x-ray at a standard angulation and position in relation to the external anatomy of the head. It is impossible to visualize accurately the general shape of the condyle and its inclination, the size of the joint spaces, the relation of the condyle to the articular fossa, the surface of the condyle except for the profile shown, and the size, shape, position, or condition of the articular disk. We have the same difficulties with the articular fossa and the articular tubercle. It is obvious that the best we can say of temporomandibular joint roentgenography is that it is very crude. The most that it can show is gross pathology, and even when this would seem apparent, it cannot be completely trusted.

TREATMENT

The rational treatment of any disease is aimed at relieving the symptoms and clearing up the cause so that the disease can be cured and a recurrence prevented. We have, as outlined above, two separate sets of symptoms, and there are two schools of thought in treatment as in symptomatology.

Many practitioners have flagrantly and irresponsibly increased the vertical dimension, and with various appliances they have forced the condyles into artificial positions. This has been done to relieve symptoms which, at the best, have only a questionable relation to temporomandibular joint disturbances. This treatment is usually done in reference to a supposed malposition of the condyle in the articular fossa—a malposition which has been diagnosed as such by roentgenographs which are basically crude, and whose diagnostic value has yet to be proved. There has been no scientific proof offered that increasing the vertical dimension or repositioning the condyle has improved the hearing, cleared up tinnitus aurium, or cured any of the other "debatable symptoms." Junemann[54] found that audiometric examination failed to confirm any improvement in the hearing of patients who had their vertical dimensions increased. Hill[55] has pointed out that deaf people, in their intense desire to hear better, feel an improvement temporarily under any form of treatment, and he felt this was the explanation for the subjective improvement that Costen and others have reported. Even Costen[9] has admitted that increasing the vertical dimension gives only temporary relief. This lack of success in treatment would of itself tend to discredit the relationship of these "debatable symptoms" to joint disturbances.

The treatment of degenerative joint disease of the temporomandibular joint is no different from the treatment of the same disease of any other joint. The general treatment as outlined by Abrams[30] is primarily a matter of rest, and this includes the avoidance of trauma, strain, and abnormal use. He advises heat, massage, and analgesics for pain (acetylsalicylic acid and its compounds) as the primary forms of treatment. In treating degenerative joint disease of the temporomandibular joint, we must correct the occlusion so that in the various mandibular

movements there will be no trauma to the joint. This of itself may be sufficient to clear up the symptoms. However, heat and analgesics will help to make the patient more comfortable while the basic cause is being corrected. Where there has been a pathologic loss of vertical dimension, this too must be corrected. It should be emphasized that some loss of vertical dimension with age is a physiologic and not a pathologic phenomenon, and irresponsible changes in vertical dimension can wreak havoc.

Muscle spasms and bruxism present another problem. The muscle spasms are often due to the pain of an injured joint or are produced by a reflex irritation. In these patients, dental treatment will clear up the muscle spasms. Where a true bruxism is present, it is often due to emotional problems of the patient, and only psychotherapy can help. Schwartz[56, 57] has reported success with ethyl chloride sprays and tetracaine infiltrations of the muscle involved. The author has used the new muscle relaxants successfully in a few cases but in too few to draw any conclusions.

Age and heredity also produce degenerative joint disease and where these are the primary factors, dental treatment can help but little. Heat and analgesics would seem the best treatment for these patients.

Nathan[58] has had success with injections of hyaluronidase where there is limited motion of the joint with associated pain and noise. This drug promotes diffusion into the tissues and thus can restore normal tone by permitting the tissue fluids to invade the area and clear up any inflammation or its sequelae. This is a very recent treatment and so is impossible to evaluate.

PROGNOSIS

Except in hip joint involvement, no real deformity or crippling results from degenerative joint disease. Russell and Bayles[59] did not see a single case of complete ankylosis in a series of 515 patients. Complete ankylosis occurs rarely if ever in temporomandibular joint disturbances. With proper treatment, we can expect a favorable prognosis and a good functional result in degenerative joint disease of the temporomandibular joint.

SUMMARY

1. The temporomandibular joint is a ginglymo-diarthrodial joint whose anatomy and actions are still not completely known or understood.

2. Degenerative joint disease of the temporomandibular joint is widespread in its occurrence, although it is often symptomless.

3. The etiology of this disease is complex. Microtrauma, overclosure of the mandible, mandibular muscle spasms, age, and possibly heredity all play their part.

4. Local and referred pain and clicking and snapping sounds are the outstanding symptoms. Loss of hearing, tinnitus aurium, vertigo, and neuralgias are accepted as connected with these joint disturbances, but only by some investigators.

5. Roentgenography of the temporomandibular joint has little to offer at this time, and it is of uncertain value in diagnosis. Cinefluorography with image intensification may be part of the answer, but this techinque is too new to evaluate.

6. Treatment is aimed to remove the sources of trauma by correcting the occlusion and restoring the vertical dimension, where necessary, to its correct physiologic level.

7. The prognosis is good, and we can usually look forward to a good functional result.

REFERENCES

1. Hollander, J. L. (editor): Comroe's Arthritis, ed. 5, Philadelphia, 1953, Lea & Febiger, p. 691.
2. Ruffer, A.: Study of Abnormalities and Pathology of Ancient Egyptian Teeth, Am. J. Phys. Anthropol. **3**:335, 1920.
3. Breasted, J. H.: Edwin Smith Surgical Papyrus, Chicago, 1930, University of Chicago Press.
4. Bellinger, D. H.: Present Status of Arthrosis of the Temporomandibular Joint, J. Oral Surg. **6**:11, 1948.
5. Prentiss, H. J.: Preliminary Report Upon the Temporomandibular Articulation, D. Cosmos **60**:505-512, 1918.
6. Summa, R.: The Importance of the Interarticular Fibrocartilage of the Temporomandibular Articulation, D. Cosmos **50**:512-514, 1918.
7. Costen, J. B.: A Syndrome of Ear and Sinus Symptoms Dependent Upon Disturbed Function of the Temporomandibular Joint, Ann. Otol. Rhin. & Laryn. **43**:1-15, 1934.
8. Idem: Glossodynia: Reflex Irritation From the Mandibular Joint as the Principal Etiologic Factor, Arch. Otolaryng. **22**:554-564, 1935.
9. Idem: Neuralgias and Ear Symptoms Associated With Disturbed Function of the Temporomandibular Joint, J.A.M.A. **107**:252-264, 1936.
10. Idem: The Mechanism of Trismus and Its Occurrence in Mandibular Joint Dysfunction, Ann. Otol. Rhin. & Laryng. **48**:499-515, 1939.
11. Idem: Correlation of X-ray Findings in the Mandibular Joint With Clinical Signs, Especially Trismus, J.A.D.A. **26**:405-407, 1939.
12. Goodfriend, D. J.: Dysarthrosis and Subarthrosis of the Mandibular Articulation, D. Cosmos **74**:523-535, 1932.
13. Idem: Symptomatology and Treatment of Abnormalities of the Mandibular Articulation, D. Cosmos **75**:844-852, 1933.
14. Idem., pp. 947-957.
15. Idem., pp. 1106-1111.
16. Idem.: The Role of Dental Factors in the Cause and Treatment of Ear Symptoms and Disease, D. Cosmos **78**:1292, 1936.
17. Sicher, H.: Oral Anatomy, ed. 2, St. Louis, 1952, The C. V. Mosby Co.
18. Idem: Temporomandibular Articulation in Mandibular Overclosure, J.A.D.A. **36**:131-139, 1948.
19. Idem: Position and Movements of the Mandible, J.A.D.A. **48**:620-629, 1954.
20. Idem: Structural and Functional Basis for Disorders of the Temporomandibular Articulation, J. Oral Surg. **13**:275-279, 1955.
21. Shapiro, H. H., and Truex, R. C.: The Temporomandibular Joint and the Auditory Function, J.A.D.A. **30**:1147-1168, 1943.
22. Shapiro, H. H.: Anatomy of the Temporomandibular Joint. Structural Relations and Therapy, Oral Surg., Oral Med., & Oral Path. **3**:1521-1550, 1950.
23. Robinson, M.: The Temporomandibular Joint: Theory of Reflex Controlled Nonlever Action of the Mandible, J.A.D.A. **33**:1260-1271, 1946.
24. Rixford, E.: On the Temporomandibular Articulation, Int. J. Orthodontia **13**:399-410, 1927.
25. Amer, A.: Approach to Surgical Diagnosis of the Temporomandibular Joint Through Basic Studies of the Normal, J.A.D.A. **45**:668-688, 1952.
26. Landa, J. S.: A Study of the Temporomandibular Joint Viewed From the Standpoint of Prosthetic Occlusion, J. Pros. Den. **1**:601-628, 1951.
27. Sicher, H.: Temporomandibular Articulation in Mandibular Overclosure, J.A.D.A. **36**:132, 1948.
28. Robinson, M.: The Temporomandibular Joint: Theory of Reflex-Controlled Nonlever Action of the Mandible, J.A.D.A. **33**:1271, 1946.
29. Berry, H. M., and Hoffman, F. A.: Cinefluorography With Image Intensification for Observing Temporomandibular Joint Movements, J.A.D.A. **53**:517-527, 1956.
30. Hollander, J. L. (editor): Comroe's Arthritis, ed. 5, Philadelphia, 1953, Lea & Febiger, p. 692.
31. Bauerle, J. E., and Archer, W. H.: Incidence of Subluxation of the Temporomandibular Joint, J.A.D.A. **43**:434-439, 1951.

32. Bowman, K.: Temporomandibular Joint Arthrosis and its Treatment by Extirpation of the Disk, Abstracted by C. W. Waldron, The Year Book of Dentistry, Chicago, 1947, The Year Book Publishers.
33. Markowitz, H. A., and Gerry, R. G.: Temporomandibular Joint Disease, Oral Surg., Oral Med., & Oral Path. **2**:1309, 1949.
34. Ibid., **3**:75, 1950.
35. Hollander, J. L. (editor): Comroe's Arthritis, ed. 5, Philadelphia, 1953, Lea & Febiger, p. 694.
36. Bauer, W. H.: Osteoarthritis Deformans of the Temporomandibular Joint, Am. J. Path. **17**:129-141, 1941.
37. Hollander, J. L. (editor): Comroe's Arthritis, ed. 5, Philadelphia, 1953, Lea & Febiger, p. 705.
38. Wright, W. H.: Deafness as Influenced by Malposition of the Jaw, J. N. D. A. **7**:979-992, 1920.
39. Freese, A. S.: Etiology and Symptomatology of Temporomandibular Joint Disturbances New York Med. J. To be published.
40. Pippin, B. N.: Treatment of Temporomandibular Lesions Caused by Denture Mutilation, Illinois D. J. **12**:429-437, 1943.
41. Bellinger, D. H.: Arthritis of the Temporomandibular Joint—Diagnosis and Management, Henry Ford Hosp. Med. Bull. **2**:56-67, 1954.
42. Brussell, I. J.: Temporomandibular Joint Diseases: Differential Diagnosis and Treatment, J.A.D.A. **39**:532-544, 1949.
43. Lindblom, G.: Disorders of the Temporomandibular Joint, J.A.D.A. **49**:28-38, 1954.
44. Schreiber, H. R.: An Anatomic and Physiological Approach to Treatment of Temporomandibular Joint Disturbances, J.A.D.A. **48**:261-265, 1954.
45. Sicher, H.: Structural and Functional Basis for Disorders of the Temporomandibular Articulations, J. Oral Surg. **13**:278, 1955.
46. Schwartz, L. L.: Pain Associated With the Temporomandibular Joint, J.A.D.A. **51**:394-397, 1955.
47. Ricketts, R. M.: Variations of the Temporomandibular Joint as Revealed by Cephalometric Laminagraphy, Am. J. Orthodontics **36**:877-898, 1950.
48. Idem: Various Conditions of the Temporomandibular Joint as Revealed by Cephalometric Laminagraphy, Angle Orthodont. **22**:98-115, 1952.
49. Idem: Laminagraphy in the Diagnosis of Temporomandibular Joint Disorders, J.A.D.A. **46**:620-648, 1953.
50. Idem: The Role of Cephalometrics in Prosthetic Diagnosis, J. Pros. Den. **6**:488-503, 1956.
51. Gillis, R.: Establishing Vertical Dimensions in Full Denture Construction, J.A.D.A. **28**:430-436, 1941.
52. Riesner, S. E.: Temporomandibular Joint: Roentgenographic Diagnosis and Clinical Importance, Arch. Clin. Oral Path. **4**:19-40, 1940.
53. Idem: Temporomandibular Articulation: Its Consideration in Orthodontic Diagnosis, Int. J. Orthodontia **22**:1, 1936.
54. Junemann, H. R.: Consequences of Shortening the Intermaxillary Distance, J.A.D.A. **28**:1427-1441, 1941.
55. Hill, F. T.: The Changing Conception of the Management of Chronic Progressive Deafness, Ann. Otol. Rhin., & Laryn. **51**:653, 1942.
56. Schwartz, L. L.: Ethyl Chloride Treatment of Limited Painful Mandibular Movement, J.A.D.A. **48**:497, 1954.
57. Schwartz, L. L., and Tausig, D. P.: Temporomandibular Joint Pain—Treatment With Intramuscular Infiltration of Tetracaine Hydrochloride: A Preliminary Report, New York D. J. **20**:219, 1954.
58. Nathan, A. S.: The Use of Hyaluronidase in Temporomandibular Disturbances, Oral Surg., Oral Med., & Oral Path. **7**:368-377, 1954.
59. Russell, L. A., and Bayles, T. R.: The Temporomandibular Joint in Rheumatoid Arthritis. J.A.D.A. **28**:533-539, 1941.

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DETECTION OF DISCONTINUITIES IN PORCELAIN TEETH

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NEARLY ALL DENTISTS HAVE encountered the situation in which, shortly after the insertion of a prosthetic appliance, the patient returns with a tooth missing. Characteristically, this situation results from a fracture within the tooth structure rather than from the loss of the entire tooth.

The frequency of this occurrence has prompted an investigation to determine the possible incidence of hidden defects and the result of these defects upon the compressive strength of artificial teeth. A method was developed which would determine the presence of discontinuities (fracture or check lines) more minute than could be observed by the unaided eye. This procedure is based upon a technique utilized by the ceramic industries.[1]

METHODS AND PROCEDURE

The procedure consisted of dipping the tooth into an electrolytic solution for one minute to permit the electrolyte to enter the defective area. The tooth surface was then blotted dry with a paper towel so that the tooth was completely dry except for the presence of the dip solution retained within the depths of the discontinuities (Fig. 1*a*). A finely powdered preparation of calcium carbonate was then blown onto the dry surface of the tooth. The passage of the powder through the hard rubber discharge tube of the unit (Fig. 2) rendered the powder predominantly positive. Since the negative ions of the electrolyte attracted the positively charged particles of calcium carbonate, a visible mass of the powder accumulated at the surface of the discontinuity (Fig. 1*b*).

With the utilization of light reflection, the unaided eye can detect a discontinuity as small as 0.1 micron on a piece of glass.[2] This method is not practical on a porcelain tooth. The technique, which makes use of an electrified-particle inspection, permits observation of defects, the only requirement being that the interfaces of the defect be separated sufficiently to allow passage of the electrolyte. This technique, in effect, magnifies the previously invisible defects.

RESULTS

It was believed that thermal shock, incurred during certain procedures in the construction and processing of prosthetic devices, was responsible, in part,

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for the discontinuities produced in porcelain teeth. Consequently, experiments were performed in which thermal shock was produced by rapid reduction in temperature after the application of wet or dry heat. The teeth were evaluated for loss in crushing strength by subjecting them to a uniform compressive load in a screw vise with a load-indicator dial. The indicator recorded the crushing point by means of a second hand which remained at the maximum load point attained at the moment of fracture.

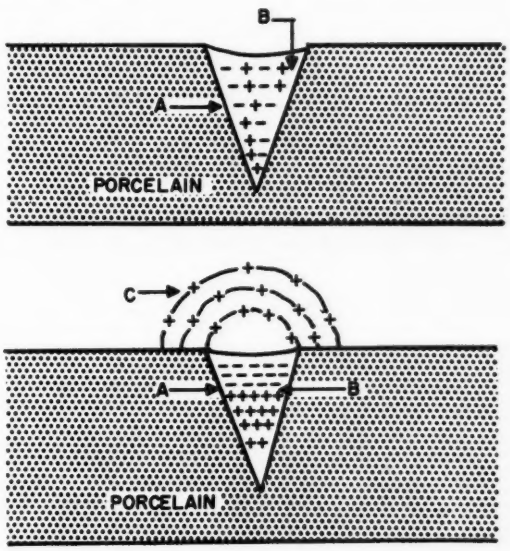

Fig. 1.—*a*, The electrolyte retained within the discontinuity: (*A*) discontinuity or check line; (*B*) electrolyte. *b*, The positively charged particles of calcium carbonate accumulated at the surface of the discontinuity: (*A*) interface of the discontinuity; (*B*) electrolyte (note molecular arrangement); (*C*) positively charged calcium carbonate.

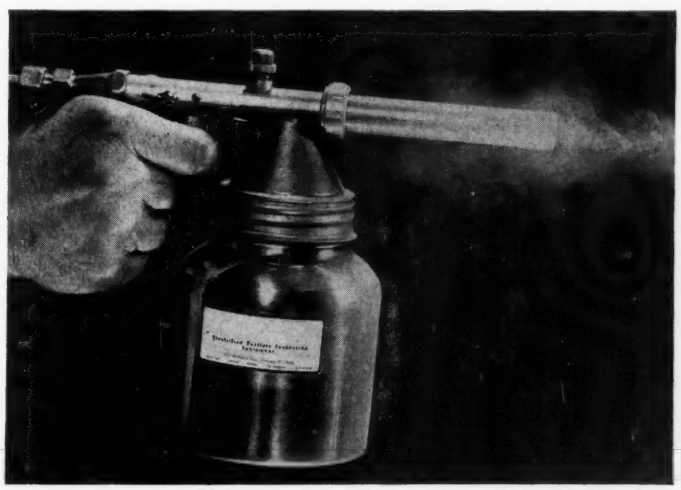

Fig. 2.—The instrument used to blow a finely powdered preparation of calcium carbonate onto the surface of the tooth.

EFFECTS OF WET HEAT THERMAL SHOCK

A test was made to determine the effect of thermal shock created by wet heat. Fifty each of three different brands of porcelain teeth were inspected by the electrified-particle method to determine the presence of discontinuities prior to the test procedure. Only those teeth without surface defects were used. For control purposes these teeth were crushed by the pressure test mechanism to determine the average crushing-point load.

Ten *Brand B* teeth were tested for surface discontinuities; none were detected. These teeth were then heated to 150° F. in cottonseed oil and allowed to heat soak for 10 minutes. The teeth were removed and immediately dipped into a 40° F. water bath. After removal from the water bath, the teeth were inspected for visible defects and then tested by the electrified-particle inspection method.

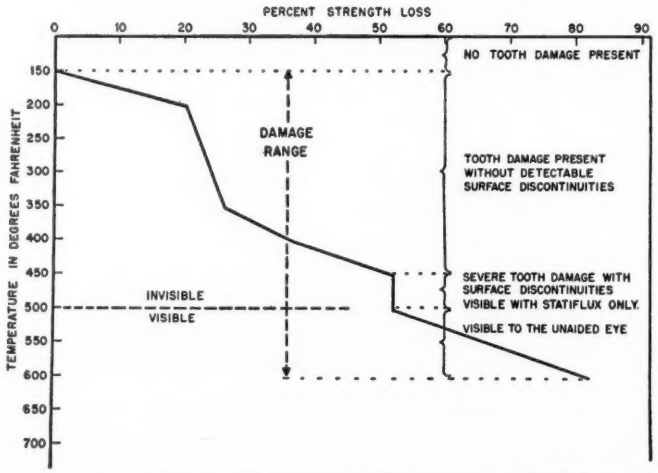

Fig. 3.—Loss of compression strength under wet heat in Brand B teeth.

No discontinuities were seen. A determination of crushing strength indicated no loss. This procedure was carried out at 50° F. intervals from 150° F. to 600° F. Fig. 3 indicates the percentage of load loss at the various temperatures employed, and the ranges at which damage occurred to all teeth. These ranges were: (1) a temperature range which produced no tooth damage; (2) a temperature range which produced tooth damage but no surface discontinuities (later referred to as the "fatigue range"); (3) a temperature range which produced surface discontinuities, but of such insufficient magnitude as to be visible only by electrified-particle inspection (later referred to as the "invisible-detectable range"); and (4) a temperature range which produced visible damage.

Brand B.—These teeth showed no defects or strength loss as a result of wet heat up to 150° F. (Fig. 3). Repeated heating and cooling at 150° F. or below did not produce detectable damage to the teeth nor cause a reduction in compressive load strength. At 200° F., 20 per cent of the compressive load strength was lost, but damage was not detectable visually or by the electrified-particle inspection procedure. At 250°, 300°, and 350° F., a very gradual rise in load loss was noted. At 400° F., a total of 36 per cent of the total strength of the tooth was lost; damage was still not detectable.

The range at which Brand B tooth damage was first noted, up to but not including 450° F., is referred to as the "fatigue range." Temperature limitations of the fatigue range varied with each brand. Repeated heating and cooling within the fatigue range caused the teeth to present characteristics identical to the next higher range (the "invisible-detectable" range). This phenomenon occurred in all teeth which were subjected to this procedure.

It is therefore postulated that this loss of strength was caused by a porcelain fatigue similar to metal fatigue which can occur without surface discontinuities.

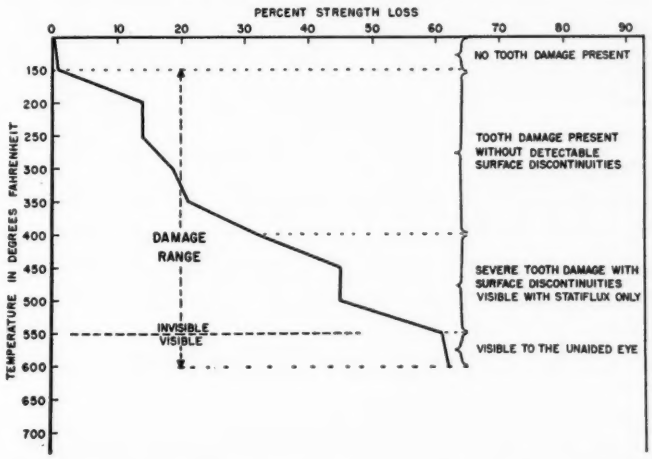

Fig. 4.—Loss of compression strength under wet heat in Brand A teeth.

Fig. 5.—Electrified-particle indication of the gradual rise in the severity of damage caused by thermal shock after the application of wet heat.

Brand A.—This brand of porcelain tooth, when subjected to wet heat, showed essentially the same graph curve as the previous group with the exception that resulting loss of compressive strength was slightly less for equivalent temperature

(Fig. 4). Electrified-particle inspection first indicated damage at 400° F., with a relatively long fatigue range. Visible damage was noted at 550° F. with a 61 per cent loss of strength at that temperature. Fig. 5 illustrates electrified-particle indication of the gradual rise in the severity of damage caused by thermal shock after application of wet heat.

Brand C.—The same test on Brand C teeth produced a somewhat similar graph in that all four ranges were present (Fig. 6). The teeth were found to be somewhat more resistant to thermal shock in the lower heat range—extending from room temperature to 300° F. It is interesting to note that these teeth showed exactly the same "invisible-detectable range" as did Brand A (Fig. 4); that is, electrified-particle inspection showed defects at 400° F. in both instances, and visible defects at 550° F. with 61 per cent compressive strength loss on both.

EFFECTS OF DRY HEAT THERMAL SHOCK

Thermal shock with dry heat was accomplished in the following manner. Fifty each of three different brands of porcelain teeth were inspected by the electrified-particle method prior to thermal shock testing to discover the possible presence of discontinuities. None were found. Ten each of the teeth were then placed in a covered porcelain dish and exposed to heat for 10 minutes at the specified oven temperatures. The teeth were then dropped into a 40° F. water bath.

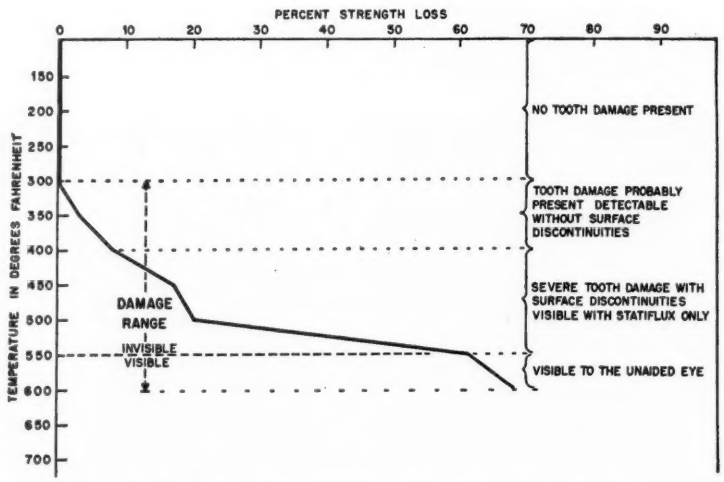

Fig. 6.—Loss of compression strength under wet heat in Brand C teeth.

Brand B.—Up to a temperature of 150° F., no damage was noted; beyond that heat range and up to 250° F., a gradual decrease in crushing strength occurred without apparent damage to the tooth surface. This observation appears quite typical of the "fatigue range" phenomenon in the teeth thermally shocked after wet heat at 250° F. The first defects were visible by the electrified-particle procedure. This point was the beginning of the "invisible-detectable range." Defects were first visible to the unaided eye at 450° F. at which point 40 per cent of the tooth's crushing strength had been lost (Fig. 7). It is interesting to note that dry heat at

the high temperature ranges did not produce the reduction in crushing strength that was produced with wet heat.

Brand A.—The effects of subjecting 10 Brand A porcelain teeth to dry heat temperatures of from 150° to 700° F. at 50° F., intervals are plotted in Fig. 8. It is to be emphasized that 10 new teeth were used for each 50° F. increase in temperature. Visual inspection and electrified-particle inspection were accomplished on the 10 teeth in each heat range. Crushing strength determinations were

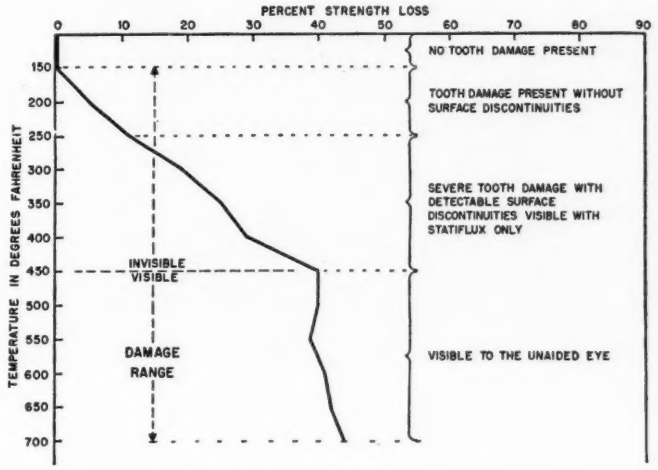

Fig. 7.—Strength loss under dry heat in Brand B teeth.

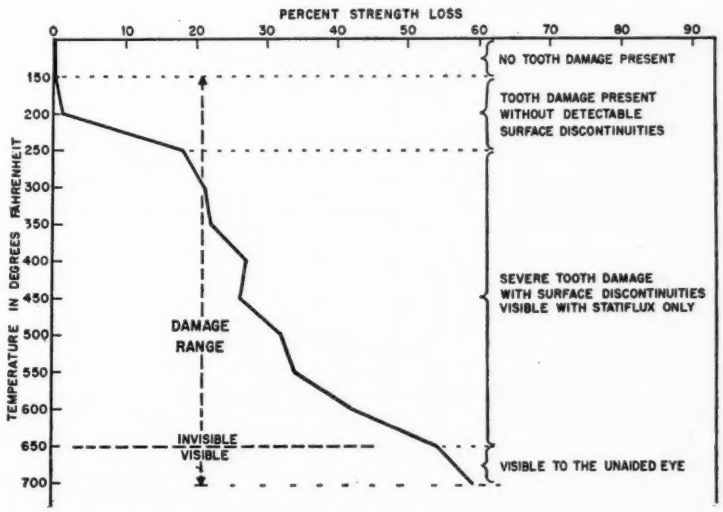

Fig. 8.—Strength loss under dry heat in Brand A teeth.

made on each tooth in the entire series. Fig. 9 represents the effect of dry heat and thermal shock on Brand A teeth as detected by the accumulation of electrified particles at the discontinuities.

Brand C.—When subjected to dry heat and thermal shock of 200° F., porcelain teeth exhibited a slight loss in crushing strength which increased to a 11.0 per cent loss at 350° F. (Fig. 10). At this point, the damage was detectable

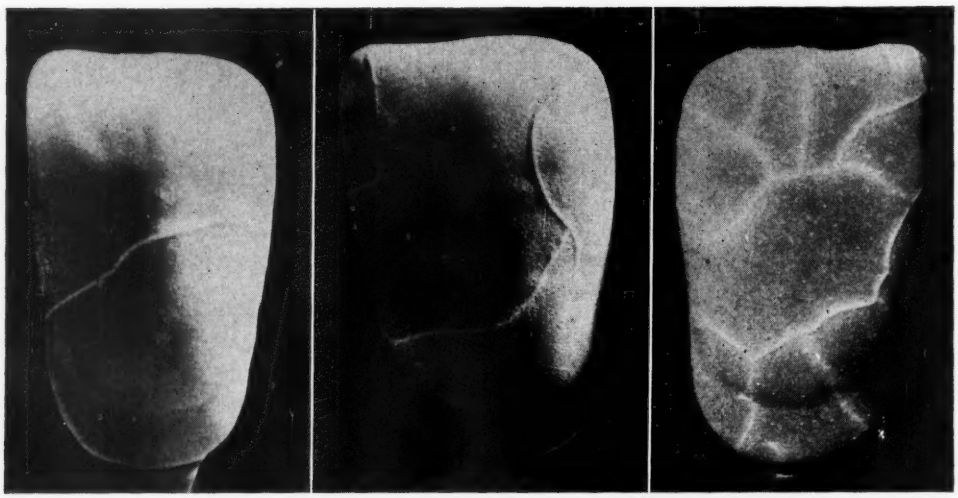

Fig. 9.—The effect of dry heat and thermal shock on Brand A teeth as detected by the accumulation of electrified particles at the discontinuities.

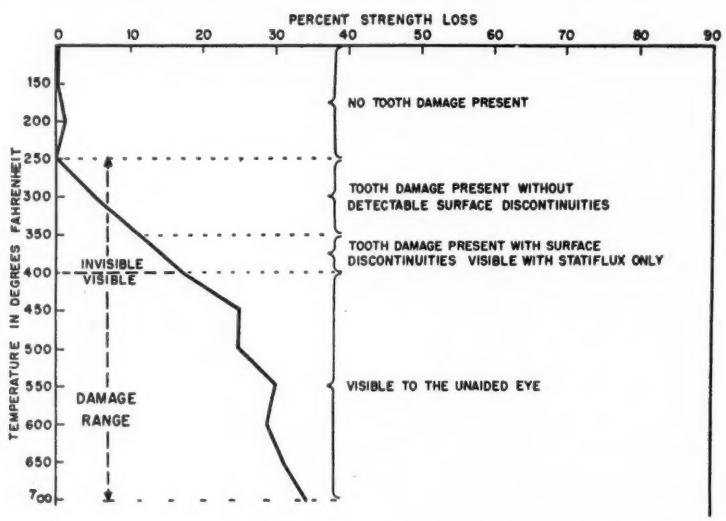

Fig. 10.—Strength loss under dry heat in Brand C teeth.

by the electrified-particle inspection method. Damage in the form of discontinuities was not visible to the unaided eye until the temperature of 400° F. was attained. A 17 per cent loss in strength occurred at this temperature.

DISCUSSION

Surface discontinuities, such as those produced on porcelain teeth by thermal shock after wet and dry heat, could conceivably be produced by routine laboratory procedures. When this damage can be detected by the unaided eye, a 17.0 per cent to 61.0 per cent reduction in crushing strength is manifest. Laboratory manipulation of ceramic teeth should avoid any technique which would tend to produce thermal shock in artificial porcelain teeth. Such techniques as flaming a waxed trial denture and plunging it into cold water in order to polish and improve the finish of the wax could produce thermal shock and discontinuities in the teeth. Certain rebasing procedures that permit the technician to burn off the acrylic resin around the teeth should be avoided.

A technique which utilizes the electrified-particle inspection method would permit detection of check lines or discontinuities in porcelain teeth before they would be visible to the unaided eye. This procedure would offer a rapid, inexpensive technique which could be successfully employed in any large laboratory for detecting imperfections not commonly visible in porcelain teeth after processing. This technique could prove of value in the construction of porcelain jacket crowns as a method for determining optimum manipulative procedures that would increase the strength of the completed jacket and for preventing fractures due to imperfections in construction.

SUMMARY

Porcelain teeth were tested by an electrified-particle inspection method to determine whether thermal shock would produce discontinuities on the surface and, if so, what effect this treatment might have on the relative compressive strength of the teeth. Tests were made employing both wet and dry heat. In all instances, electrified-particle inspection showed defects before they were otherwise visible. In some instances, 61 per cent of the strength of the tooth was lost before discontinuities (check lines) became visible to the unaided eye. It was determined that a direct ratio existed between the extent of thermal shock and surface discontinuities produced on the tooth.

The author wishes to express his appreciation to Dr. Earl S. Smith, professor emeritus, State University of Iowa, and prosthetic consultant to Chanute Air Force Base, Illinois, for his review and suggestions for experimental design; to Henry S. Staats, manager, Special Products Department, Magnaflux Corporation, for his technical advice; and to Major Jack L. Hartley, School of Aviation Medicine, USAF, for his assistance.

REFERENCES

1. Statiflux, Special Products Department, Magnaflux Corporation, Chicago, Ill.
2. Sears, F. W.: Principles of Physics, ed. 3, Cambridge, Mass., 1948, Addison-Wesley Press.

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AN ELECTROMYOGRAPHIC ANALYSIS OF MUSCULAR BEHAVIOR IN MANDIBULAR MOVEMENTS FROM REST POSITION

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ONE NEEDS ONLY TO READ the dental literature of the last twenty years to appreciate the significant role rest position and vertical dimension have played in the physiology of the masticating machine.

The prosthodontist of today is still on the quest for a solution to at least two problems. The first is a reliable method for establishing vertical height and rest position, and the second is a method for determining the correct interocclusal distance necessary between the teeth of the respective arches which will permit the muscles of mastication to function within their most efficient physiologic length. Because fundamental knowledge is still needed in these areas, a study was designed to show how the mandibular postural muscles behave in edentulous subjects whose limits of interocclusal distance had been violated by prosthetic appliances.

Since mandibular posture is neuromuscularly controlled, we deemed it advisable to determine, first, if physical rest position of the mandible determined roentgenographically was synonymous with electrical rest of its muscles viewed electromyographically. Secondly, we wanted to determine the behavior of antagonistically functioning muscles attached to the mandible when the teeth of a lower denture occluded with the teeth of the upper denture through a normal, through a larger than normal, or through a smaller than normal interocclusal distance. To do this, the muscular behavior of the same postural muscles attached to the mandible was appraised electromyographically for rest position, and for mandibular movements from rest position in horizontal and vertical planes.

Opening and closing movements of the jaws in speech, in chewing, and in respiration are functional movements. These movements may be truly vertical or truly horizontal, or they may be a combination of movements in both planes. Whichever they are, they are a result of changes in tension in the substance of the muscles in functionally reciprocating muscle teams spanning the skeletal levers of the temporomandibular joints. These muscles, which move the mandible and its two condyles in their respective fossae in mastication, in speech, and in respiration through the interocclusal distance, are controlled, by reflex or cortically, by the nervous system. This temporomandibular joint muscle complex and its neurocontrols are viewed by the physiologist as the part responsible for movements inherent to the chewing machine. These joints and their antagonistically attached muscles are subject to laws of biomechanics, as are muscles of the other movable joints in the body.

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To orient our thinking on what occurs when postural muscles of the mandible are made to function through a greater than normal or lesser than normal interocclusal distance, it is essential that we give some consideration to an analysis of the basic structure, to the mechanics, and to the neuromuscular controls of these muscles.

MUSCLE STRUCTURE

The skeletal muscles of the body are divided into three general types. They may be long-fibered, short-fibered, or pennate-fibered (Fig. 1). The long-fibered muscles have their motor units arranged in series and are found about skeletal levers having a wide range of movement. These muscles have a design capable of rapid movements. The parallel arrangement of motor units found in short-fibered

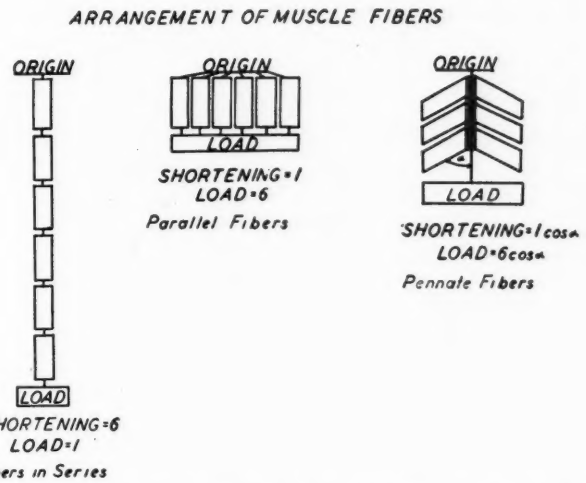

Fig. 1.—Types and arrangement of fibers in striated muscles. (From Jarabak, J. R.: Angle Orthodont. 24:196, 1954.)

muscles permits these muscles to perform heavy work. The greatest efficiency for fine postural movements comes from a featherlike arrangement of the motor units of pennate and bipennate muscles. The elevator, the protrusor, and the depressor muscles of the mandible are not made up of single muscle types. They are more frequently made up of two and, on occasions, of all three muscle types. The type of fibers most prevalent in the muscle determines the movement and the type of work this muscle performs on the mandibular lever.

MOTOR UNIT

Muscle fibers are banded together to make functional units; these are called motor units. Motor units come in various sizes; some have several hundred fibers, and some have few. Those with many fibers are found in muscles performing menial tasks. Those doing intricate operations have the fewest fibers.

Each motor unit has its own blood and a dual nerve supply. In its nerve supply, there is a motor nerve which brings impulses to the muscle from the brain and from various reflex levels (Fig. 2, *3,4,5*). These impulses activate the fibers in the muscle to contract, that is, get shorter. This property of muscle moves us

about in our daily work and activates many systems in our body which are responsible for our intrinsic well-being.

In addition to the motor nerve supply, muscle has interspersed in its muscle fibers and in the connective tissue at the end of its fibers, small sensory end-organs which record tension when muscle fibers contract or when they are stretched by opposing muscles. These sensory end-organs are called proprioceptors or "signalers." These "signalers" are individually connected by small sensory nerves

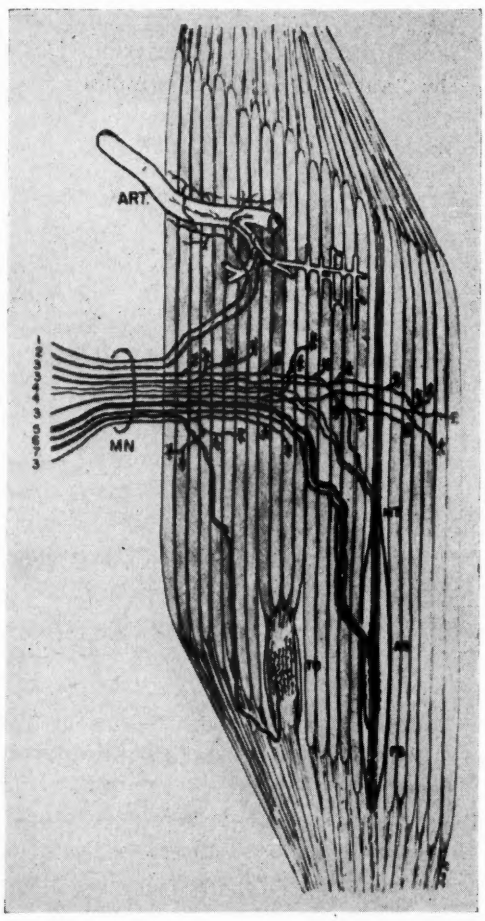

Fig. 2.—A motor unit. (From Adams, Denny-Brown, and Pearson, 1953, Diseases of Muscle, Paul B. Hoeber, Inc.)

to the spinal cord. Small nerves of this type (Fig. 2, *6,7,8*) carry signals induced by changes in stretch and in muscle tension from the muscles of mastication to the brain stem. These messages are afferent impulses. Thus, in a sense, a motor unit, functionally speaking, is a closed circuit operated by its own feedback neuromuscular mechanism.

When a motor unit contracts, it yields a small quantity of electrical energy. This energy is called an action current or an action potential. The magnitude

of these action currents determines how many motor units are contracting at a given time. Thus, if the action currents are large, that is, if they have a large amplitude, many motor units are contracting, and conversely, if the action currents have a low amplitude, fewer motor units are in action. The study of these action currents from functioning muscles with sensitive electronic devices is called electromyography, a branch of electrophysiology.

NEUROMUSCULAR MECHANISM

Early in its embryonic development, the stomatognathic system is endowed with a neuromuscular control mechanism. This mechanism is designed to operate the chewing machine, for the most part, on a reflex level.

Although the stomatognathic system is generally considered to be made up of teeth, muscles, bones, joints, and a neurocontrol apparatus, at birth and in late adulthood teeth are absent from it. Therefore, during these two periods when the stomatognathic system functions without benefit of teeth, the reflex neurocontrol mechanism responsible for its activity must come from the sensory end-organs in the capsules of the temporomandibular joints and from the sensory end-organs found in the muscles responsible for mandibular posture.

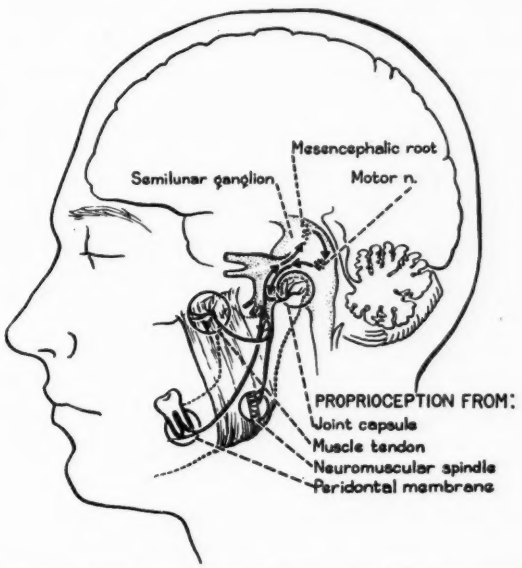

Fig. 3.—Neuromuscular reflex arcs from muscles of mastication, temporomandibular joints, and periodontal membranes.

Because this neurocontrol system plays such an important role in mandibular posture at rest and in the phasic movements in mastication, some consideration will be given now to its design.

At birth, in the capsules of the temporomandibular joints and in the muscles of mandibular posture and their tendons, are found groups of "signalers," or proprioceptors. These record tension from the capsules, from the muscles and their tendons while the mandible is at rest position, and during the phasic movements of the mandible (Fig. 3). From these "signalers," messages recording changes

in tension brought to bear on them are carried by individual nerves to nerve cells in a rootlike structure in the brain stem. This rootlike structure is the mesencephalic root of the trigeminal nerve. From here, the messages of tension resulting from stretch of the "signalers" is transferred to a "driver" nucleus which sends out long nerve arms, axons, to the muscles of mandibular posture, commanding them to contract in various degrees in response to the sensory stimuli from the proprioceptors. The "driver" nucleus is the motor nucleus of the trigeminal nerve. From this nucleus, the muscles of mastication get their motor nerves supply. Because this motor nucleus lies immediately lateral to the mesencephalic root in the brain stem, proprioceptive reflexes are readily mediated at this level. These are the simplest type of reflexes, commonly referred to as monosynaptic reflex arcs. It is believed these two neuron reflex arcs are almost wholly responsible for reflex mandibular posture.

The same neural mechanism which maintains mandibular posture in the infant before the teeth erupt is called upon to maintain it in the adult when the teeth are lost. However, it must be realized that for a span of time, that is, from the eruption of the first deciduous teeth to the loss of the last permanent teeth, postural movements of the mandible are dictated principally by proprioceptive stimuli from "signalers" in the periodontium, in the capsules of the temporomandibular joints, and in the muscles operating on these joints. While teeth are present, stimuli from periodontal proprioceptors are much more selective than are those which arise from the more primitive "signalers" of the temporomandibular joint capsules, and from the muscles and their tendons. Because of this greater selectivity, periodontal stimuli take over the dominance of many neuromuscular reflexes which govern temporomandibular joint activity.

How long the images of the periodontally dictated stimuli remain in the brain's memory banks after the teeth are lost we do not know, but we might surmise it would depend on two factors. The first is: for how long were the stimuli imposed? The second: how far from normal was muscular activity which these stimuli imposed? Ultimately, after the teeth are lost, mandibular posture is returned to the dominance of the more primitive "signalers" found in the capsular ligaments and in the muscles of mandibular posture.

MUSCLE MECHANICS

In 1882, Fick[1] described two types of muscle contraction. One he called isotonic contraction. In isotonic contraction, there is a physical shortening of the muscle fibers just as occurs when the mandibular elevating muscles raise the mandible in a chewing stroke. The other he called isometric contraction. In this type of contraction, there is no shortening even though the muscles generate tension, frequently a great tension. Therefore, in isometric contraction no external work is done. An example of isometric contraction is obtained when one attempts to crack a hard nut between the teeth. Although Fick's definition clearly states what happens when the agonist muscles are contracting, it neglects to mention what the antagonist muscles are doing during this time. For what is

taking place in the antagonist muscles while the agonists are contracting, we use a more recent definition by Höber.[2]

Höber divides muscle contraction into three types: (1) that which is accompanied by the physical shortening of muscle is isotonic; (2) that which is accompanied by muscle lengthening is also isotonic; and (3) isometric contraction obtains when muscle tension develops with no change in muscle length.

Until now this discussion has centered around the basic structure, the mechanics, and the neuromuscular controls of the musculature responsible for mandibular posture. This was done because it was necessary, first, to place the chewing machine on a neuromuscular plane of reference, a plane from which rest position and movements from this position can be more readily understood and studied by physiologic methods.

We are ready now to consider what occurs electromyographically in some of the postural muscles attached to the mandible when this bone is suspended by them in rest position. We are also ready to appraise neuromuscular activity for movements in horizontal and vertical planes starting from rest and terminating in rest position. But first, a brief consideration relative to what has already been said on rest position is in order, as is also an outline of the experimental discipline followed in this study.

REST POSITION AND THE INTEROCCLUSAL DISTANCE

Most definitions refer to the space between the teeth of the two arches as a free-way space when the mandibular musculature is at rest. For example, John Hunter[3] said: "In the lower jaw as in all joints of the body, when the motion is carried to its greatest extent, in any direction, the muscles and the ligaments are strained and the person is made uneasy. The state, therefore, into which every joint naturally falls, especially when asleep, is nearly the middle between the extremes of motions, by which means all muscles and ligaments are equally relaxed. Thence, it is that commonly and naturally the teeth of the two jaws are not in contact, nor are the condyles of the lower jaw so far back in the cavities as they can go."

Thompson[4] defines it in the following manner: "When the mandible is in rest position and interocclusal clearance (free-way space) of two, three or more millimeters (with individual variations) exists between the maxillary and the mandibular teeth. It must be thought to exist not only in the vertical but in all planes of space, viz., anteroposterior, lateral and oblique." Thompson also states: "Rest position is established before the teeth have erupted. It is not altered by the eruption of the teeth, and a high degree of stability exists to a resting position after the teeth have been lost."

While both definitions give recognition to a space between the teeth of the respective arches when the mandible is at rest, the latter emphasizes dimensional constancy in the maxillomandibular distance when the musculature is at rest, whether teeth are present or absent.

Sherrington[5] said, "Posture is the basis of movement and all movement begins and ends in posture." This definition succinctly states the physiologist's attitude on the question of rest position.

METHODS

The basic data for this article were obtained from two subjects from two groups. In one group were pooled patients with good occlusion who had no visible functional disturbances in occlusion and whose interocclusal distance ranged from 2 to 4 mm. These were used as controls. In the second group were edentulous patients. Most of these had worn dentures for some time which had functioned through an excessive interocclusal distance. In several instances, the interocclusal distance exceeded 10 mm. when the mandible, viewed cephalometrically, was in physiologic rest position.

Three dentures were made for the edentulous patient in addition to the one he had been wearing. This one had an 8 mm. interocclusal distance. The first experimental denture had a 12 mm. interocclusal distance (Fig. 4,*A*), the second a 4 mm. distance (Fig. 4,*B*), and the last had a zero distance between the teeth at rest. The last was a high denture (Fig. 4,*C*) designed to encroach on the interocclusal space. Thus, the functional vertical dimension was decreased with one denture, kept at a desirable level with the second, and increased with the third.

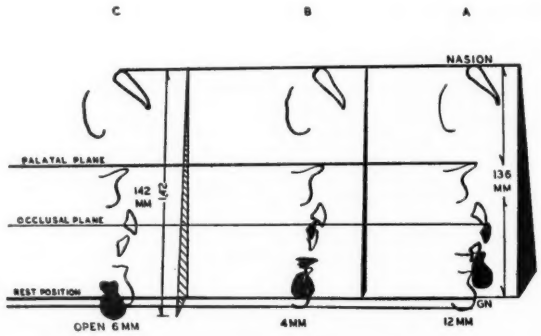

Fig. 4.—Cephalometric appraisal of maxillomandibular relations. *C*, For the greater than normal. *B*, For the normal, *A*, For lesser than normal interocclusal distance.

Electrical activity which occurs in muscles when they contract was recorded from three muscles electromyographically. Two of the muscles, the masseter and temporal, are elevators of the mandible. The third, the digastric muscle, is a mandibular depressor. From the edentulous patient, records were taken from the greatest, to the least, interocclusal distance.

The first group of data deals with muscle behavior while the mandible is in rest position. The second is for horizontal mandibular movements of nonloaded muscles: that is, protrusive, retrusive, and right and left lateral movements were made from rest position without the teeth coming into contact.

When movements in the horizontal plane were completed, activity from nonloaded muscles was recorded for movements in the vertical plane. This comprises the third group of data.

Nonloaded movements in the vertical plane were done in the following manner. First, rest position was attained, then the mandible was depressed very slowly

to about 15 mm. below rest position. The mandible was then elevated until occlusal contact of the teeth was attained. After occlusal contact was attained, the mandible slowly returned to rest position.

ELECTROMYOGRAPHIC DATA ON REST POSITION

First, we examined rest activity after the letter "M" had been repeatedly spoken. The first record was taken from the subject with a normal occlusion (Fig. 5,*A*). From this record, it is quite clear that while the mandible was in rest position, there was electrical silence in the digastric, in the masseter, and in the temporal muscles. From this we may assume that for a subject with normal occlusion, mandibular rest was synonymous with electromyographic silence in these muscles. This we found to be true for many of the younger subjects in the control group.

We considered next the muscular behavior in an edentulous subject for physiologic rest; this patient had worn dentures which at rest had an 8 mm. interocclusal distance. Test records made with or without these dentures showed some spontaneous hyperactivity at rest in the temporal and digastric muscles.

The hyperactivity heightened when a denture having a 12 mm. interocclusal distance at rest was worn briefly (Fig. 5,*B*). This hyperactivity was greater than previously seen when the patient used his original dentures or when he moved them. Thus, electromyographically, there was no muscular activity at rest in the subject with normal occlusion and an average interocclusal distance, and there was sustained spontaneous activity in the patient wearing dentures having a 12 mm. interocclusal distance. This indicates a relation between the distance a muscle contracts beyond its physiologic length and its behavior at rest.

When the interocclusal distance was reduced from 12 mm. to 4 mm. with a higher denture, the mandible attained a position at rest, in which the flexors (the depressors) and the extensors (the elevator muscles) of this bone were in equilibrium. This is attested to by a record of electromyographic silence in both muscle groups (Fig. 5,*C*).

When the vertical dimension of occlusion was increased 6 mm. beyond rest position, and the teeth were constantly in contact at rest, a low-level stretch activity occurred in the masseter and temporal muscles. This activity was due to the initiation of lengthening contraction in the mandibular elevators, that is, in the temporal and masseter muscles.

These variations in the level of activity in the temporal and digastric muscles to a varying interocclusal distance, when the mandible seemed to be in position of physical rest, raised puzzling questions: What caused spontaneous hyperactivity in rest position when the occlusal platform was at a level of greatest interocclusal clearance, and why did spontaneous hyperactivity disappear the nearer we approached, by means of prosthetic appliances, that point usually considered the normal level of interocclusal clearance? The difficulty of answering these questions is heightened if we accept the fact of neuromuscular dictation of the rest position long before the eruption of the first tooth. Let us, however, look at the rest of our data and return to these questions later.

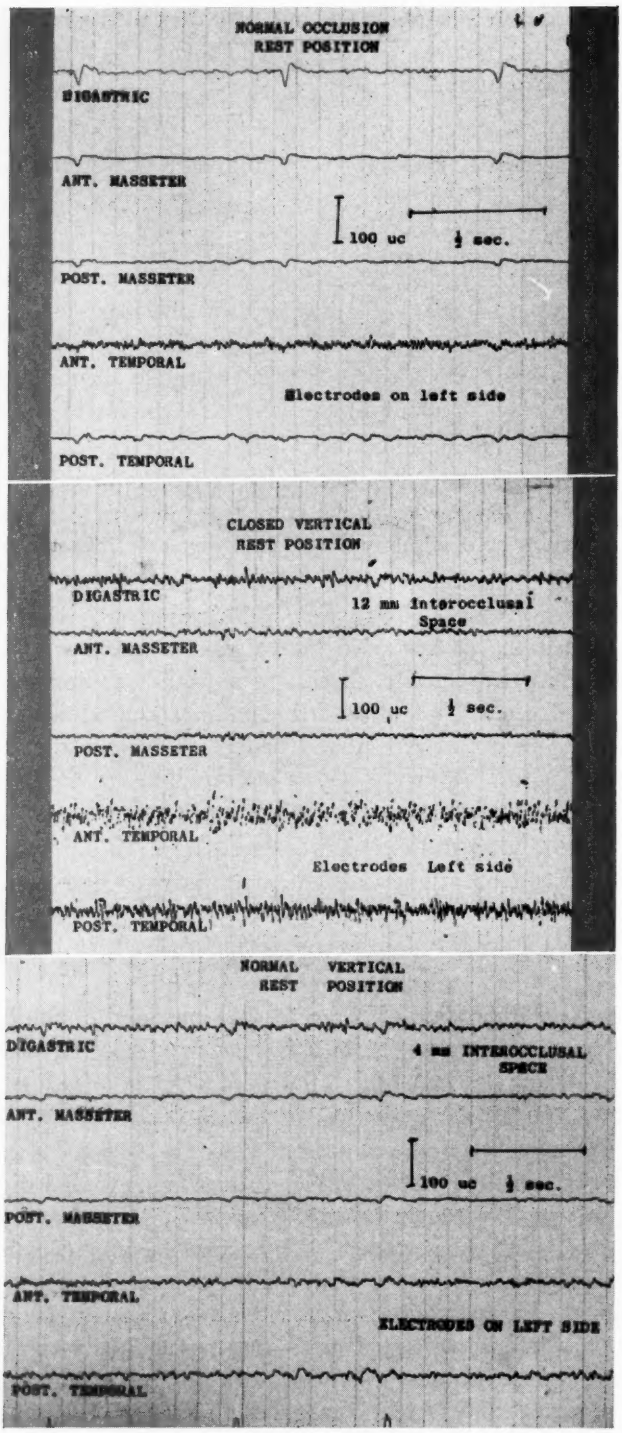

Fig. 5.—Electromyographic behavior of resting muscles. *A*, Natural dentition. *B*, Sustained spontaneous hyperactivity in the temporal and digastric muscles with dentures at 12 mm. interocclusal distance. Edentulous subject. *C*, Absence of sustained hyperactivity at rest with dentures at 4 mm. interocclusal distance.

MUSCLE ACTIVITY INHERENT TO MANDIBULAR MOVEMENTS IN A HORIZONTAL PLANE FROM REST POSITION

Right and Left Lateral Movement (No Tooth Contacts).—Muscular activity recorded from mandibular movements to the right of the rest position from the subject with a normal occlusion indicates activity in the temporal, the masseter, and the digastric muscles on both sides of the mandible (Fig. 6,*A*). Since the recording electrodes were placed on the left side,* lengthening contraction was recorded from muscles on the left side when mandible movements were to the right and for the most part shortening contraction when they were in the left. Motor activity due to muscle lengthening arising from right lateral movements of the mandible was greatest in the digastric muscle, less in the temporal and least in the masseter muscle.

For mandibular movements to the left, isotonic contraction was recorded from muscles' shortening (Fig. 6,*B*). The greatest motor activity occurred in the temporal muscles, next came the digastric, and, lastly, the masseter muscle, in which there was virtually electromyographic silence. All muscles reached the rest base line when the mandible returned to rest position.

Having examined the way some of the mandibular postural muscles behaved in right and left mandibular movements in a subject with normal occlusion, we may now speak of what takes place during similar movements in the patient having short dentures and an excessive interocclusal distance. For movements to the right, the digastric muscle behaved in the same manner (Fig. 7,*A*) as it did in the subject with a normal occlusion. However, the pattern of activity was quite different in the two other muscles. Activity was considerably greater in the masseter and temporal muscles. This occurred only when the mandible was moved to the right.

The most striking thing in these myograms was the disappearance of spontaneous hyperactivity seen in the resting digastric and temporal muscles when the mandible began to move to the right. It was replaced by greater motor activity as the latitude of this movement increased. Sustained hyperactivity continued to be absent until the movement to the right was completed, and it remained so during the return of the mandible to rest, only to reappear soon after the mandible had come to rest.

The small amount of activity recorded for the mandibular movement from rest to the left (Fig. 7*B*), though not the same in all edentulous patients, is a frequent occurrence. Here the mandible made only a partial movement to the left. This is verified by the fact that the activity from the temporal and the masseter muscles was low and similar to that seen at the beginning and ending phase of the right lateral movement. This limited excursion, to one side in some patients, to the other side in some, is due to unilateral chewing habits and is often seen clinically when needle point tracings are made.

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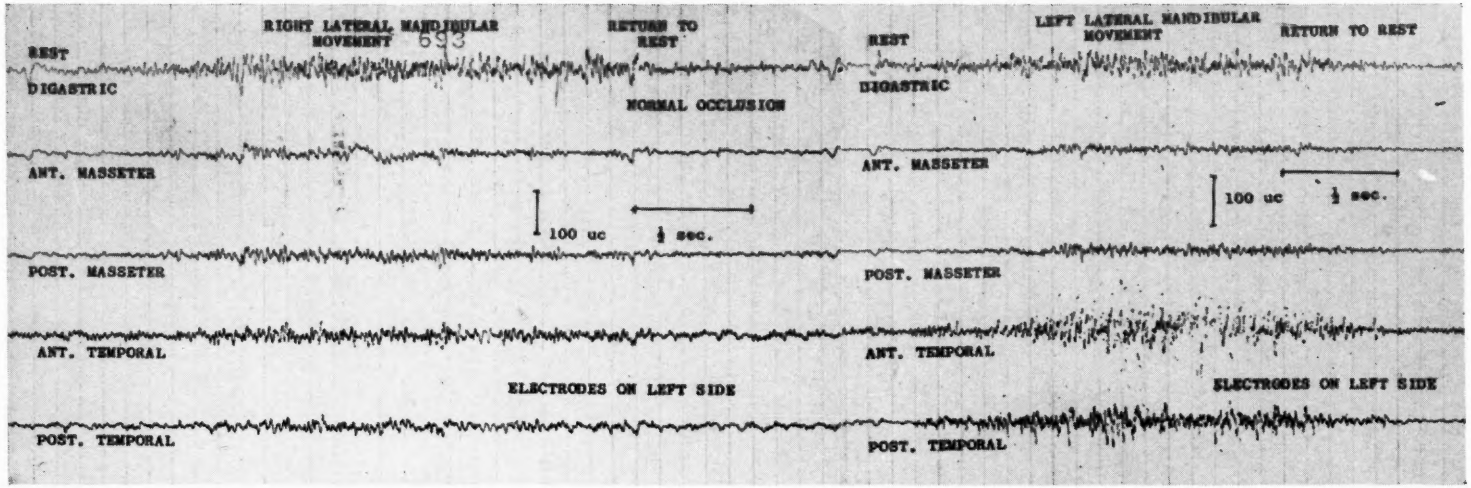
*For all phases of this experiment the electrodes were attached to the skin over the muscles on the left side.



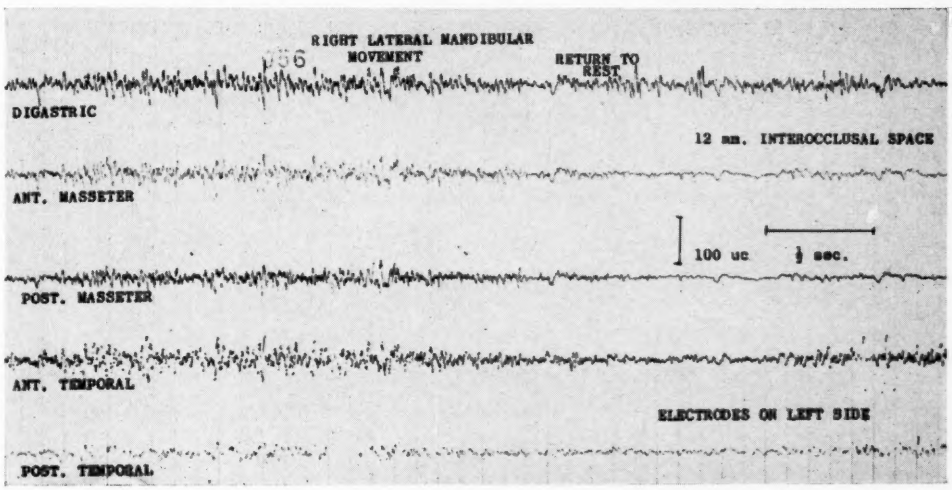
A. *B.*

Fig. 6.—*A,* Right horizontal mandibular movements. Natural dentition. *B,* Left horizontal mandibular movements. Natural dentition.

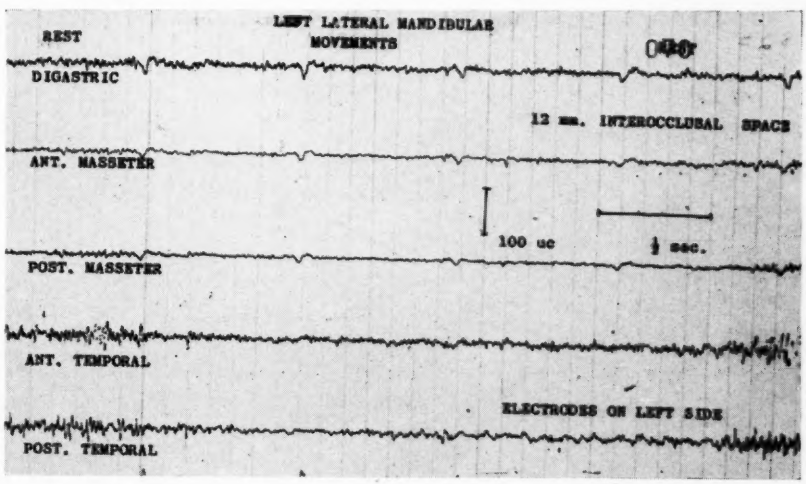
In edentulous patients, who for some time have worn dentures having a 4 mm. interocclusal distance, the mandibular depressor and elevator muscles behaved the same functionally, for movements to the right (Fig. 8,*A*), as they did in patients with normal occlusion.

Electromyographically, there was muscular silence before the movement started, and the silence returned as soon as the mandible arrived in rest position. This is identical with what took place for similar movements in the subject with normally occluding teeth having a 3 mm. interocclusal distance.

Attention is now given to the left lateral movement of the edentulous subject having dentures with a 4 mm. interocclusal distance (Fig. 8,*B*). Except for a slight



A.

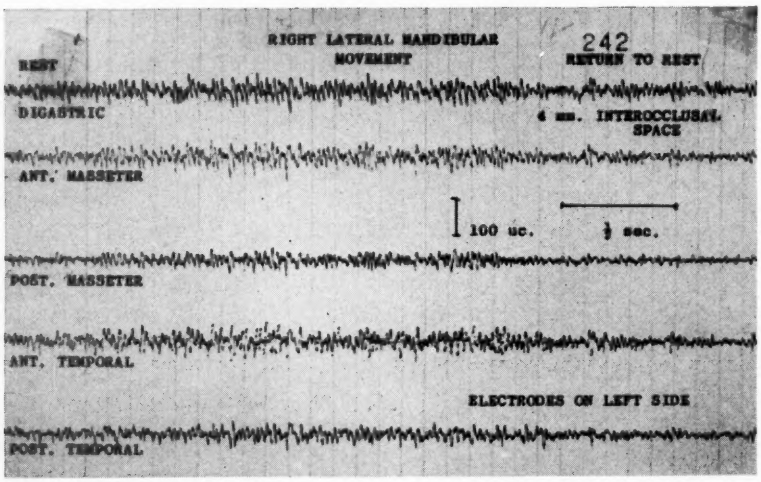


B.

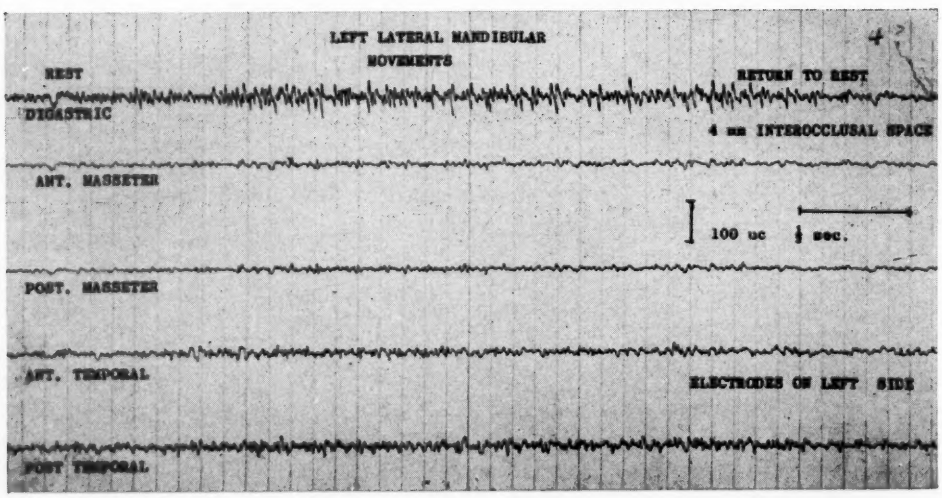
Fig. 7.—*A*, Right horizontal mandibular movements. Edentulous with a 12 mm. interocclusal distance. *B*, Left horizontal mandibular movements. Edentulous with a 12 mm. interocclusal distance.

variation which occurred in the masseter, temporal, and digastric muscles on the side toward which the movement was being effected, motor activity in the muscles under consideration was very nearly the same as that seen in Fig. 7,*B*.

When the high dentures were placed, there was constant tooth contact, because the vertical dimension had been opened (Figs. 8,*C* and *D*). The mandibular elevator muscles were placed under increased stretch tension because of this increase in vertical dimension. Since this increase in tension was present before the lateral movement was begun, some action potentials were observed at rest. These



A.

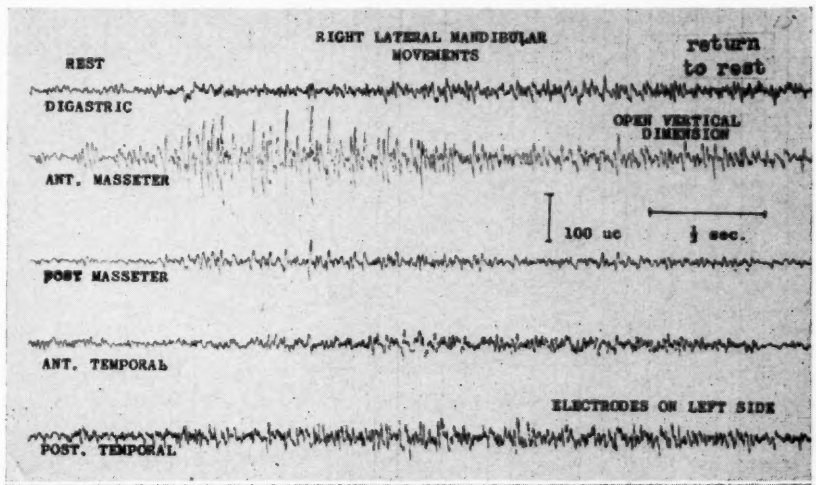


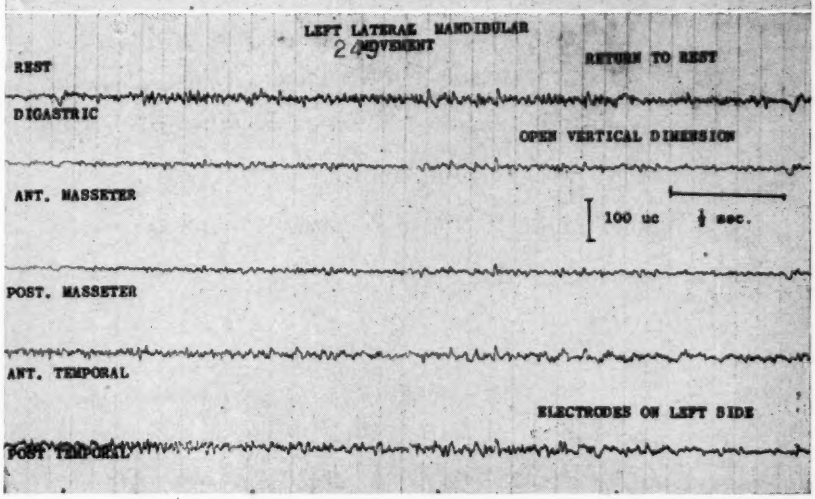
B.

Fig. 8.—*A*, Right horizontal movements. Edentulous with a 4 mm. interocclusal distance. *B*, Left horizontal movements. Edentulous with a 4 mm. interocclusal distance. *C*, Right horizontal movements. Edentulous with "high" dentures. The occlusal vertical dimension was increased 6 mm. in excess of rest. *D*, Left horizontal movements. Edentulous with the same dentures as in *C*.

potentials became progressively greater as the movement gained magnitude to the right. From this, it may be said that, as mandibular elevator muscles are stretched by prosthetic appliances beyond their resting length, more motor units are called to work to effect an increased holding action on the mandible as it makes its excursions in the direction of greater muscle stretch. (Since the recording electrodes were attached on the left side, the movement of the mandible referred to above was to the right.) The contrary was true when the mandible moved to the left, or in a direction conducive to relaxation of the muscle stretch.

C.





D.

Fig. 8, C and D.—*(For legend see opposite page.)*

PROTRUSIVE MOVEMENTS *(No Occlusal Contacts)*

For protrusive movements of the mandible one thing was common to the muscles* studied; they all showed lengthening contraction when the mandible

*Lateral pterygoid muscles were not appraised.

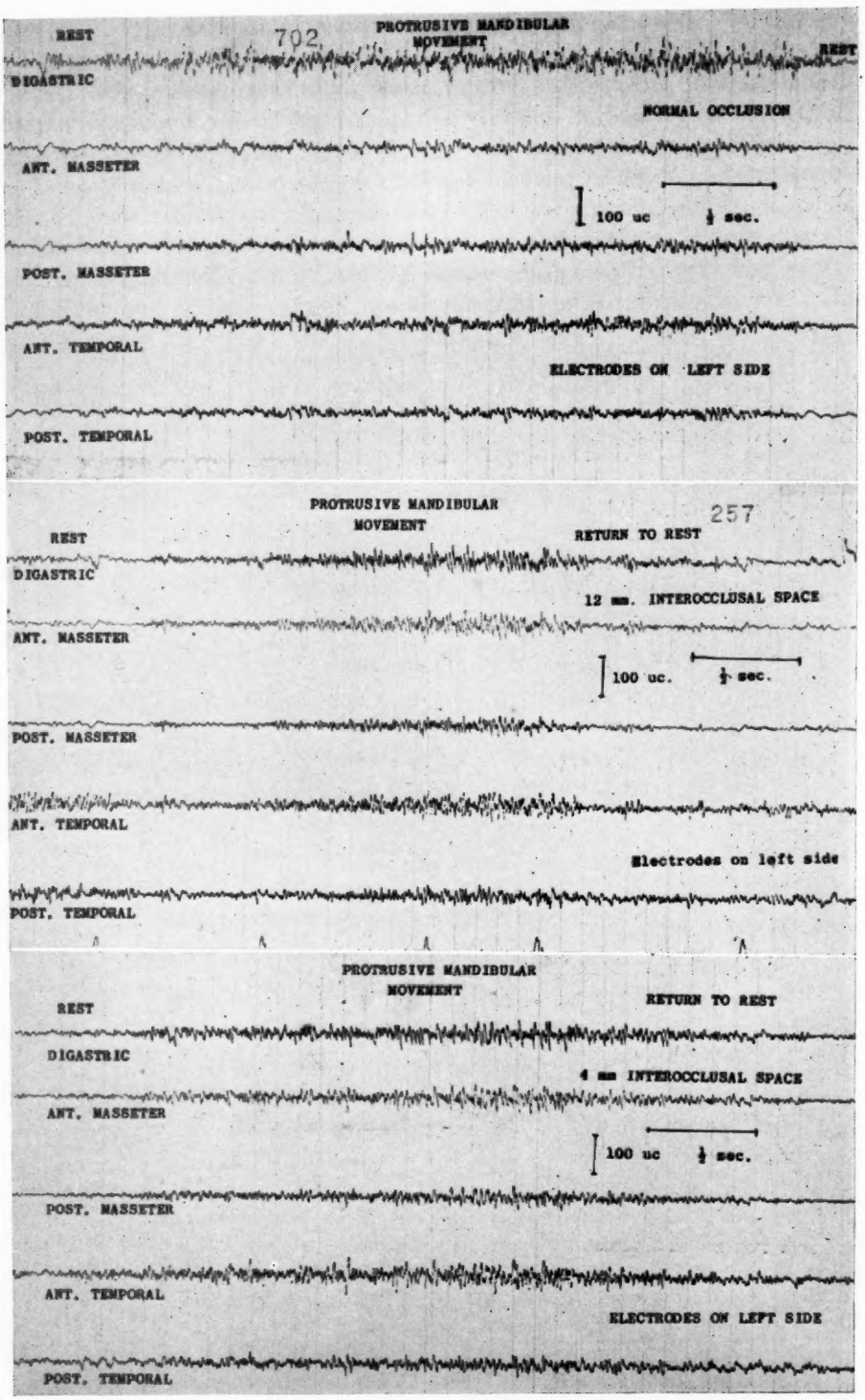
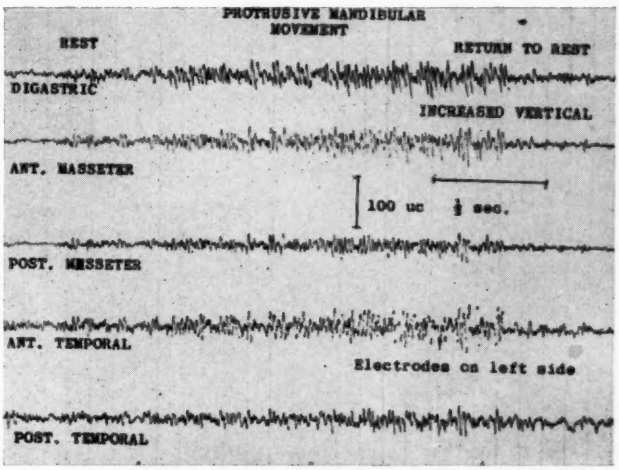


Fig. 9.—*A*, Protrusive mandibular movements. Natural dentition with a 3 mm. interocclusal distance. *B*, Protrusive mandibular movements. Edentulous with dentures having a 12 mm. interocclusal distance. *C*, Protrusive mandibular movements. Edentulous with dentures having a 4 mm. interocclusal distance. *D*, Protrusive mandibular movements. Edentulous with dentures having a vertical dimension increased 6 mm. beyond rest.

was protruded (Fig. 9*A*). Motor-unit-wise, this contraction was greatest in the subject with a normal occlusion in the digastric, diminished some in the temporal, and slightly more in the masseter muscles.

In the edentulous subject, the activity from protrusive movements was very nearly identical to that in subjects with normal occlusion (Fig. 9,*B, C, D.*).

Thus far, muscular activity shown for right lateral, left lateral, and for protrusive mandibular movements was the result of willed commands from the brain cortex.



D.

Fig. 9,*D.*—*(For legend see opposite page.)*

Retrusive Movements

Retrusive mandibular movements are clinically important for establishing centric relation. Because of this, muscular activity was studied in accordance with three disciplines, each of which has at one time or another been clinically popular. In the first, the subjects were instructed to willfully retrude the mandible under power of its musculature from rest as far back as possible. In the second, the operator placed his hand on the chin and retruded the mandible. In the third, the patients were asked to retrude the mandible with their own hands. Records of muscular activity from each discipline will be described in the order mentioned.

First, we examine the patterns of muscular behavior for voluntary retrusive movements taken from a subject with a normal occlusion (Fig. 10,*A*). The digastric muscles shortened very vigorously. Almost as vigorous was the action in the masseter muscles which were lengthening. The activity in the temporal muscle for retrusive mandibular movements is in contradiction to its anatomic structure. From the anatomic direction of the posterior fibers of this muscle, greater motor activity should have been recorded from the posterior fibers for this movement. Why do these contradictory electromyographic findings occur, or are they contradictory?

To explain why more anterior than posterior fibers in the temporal muscle contracted, for what was seemingly a retrusive mandibular movement, attention

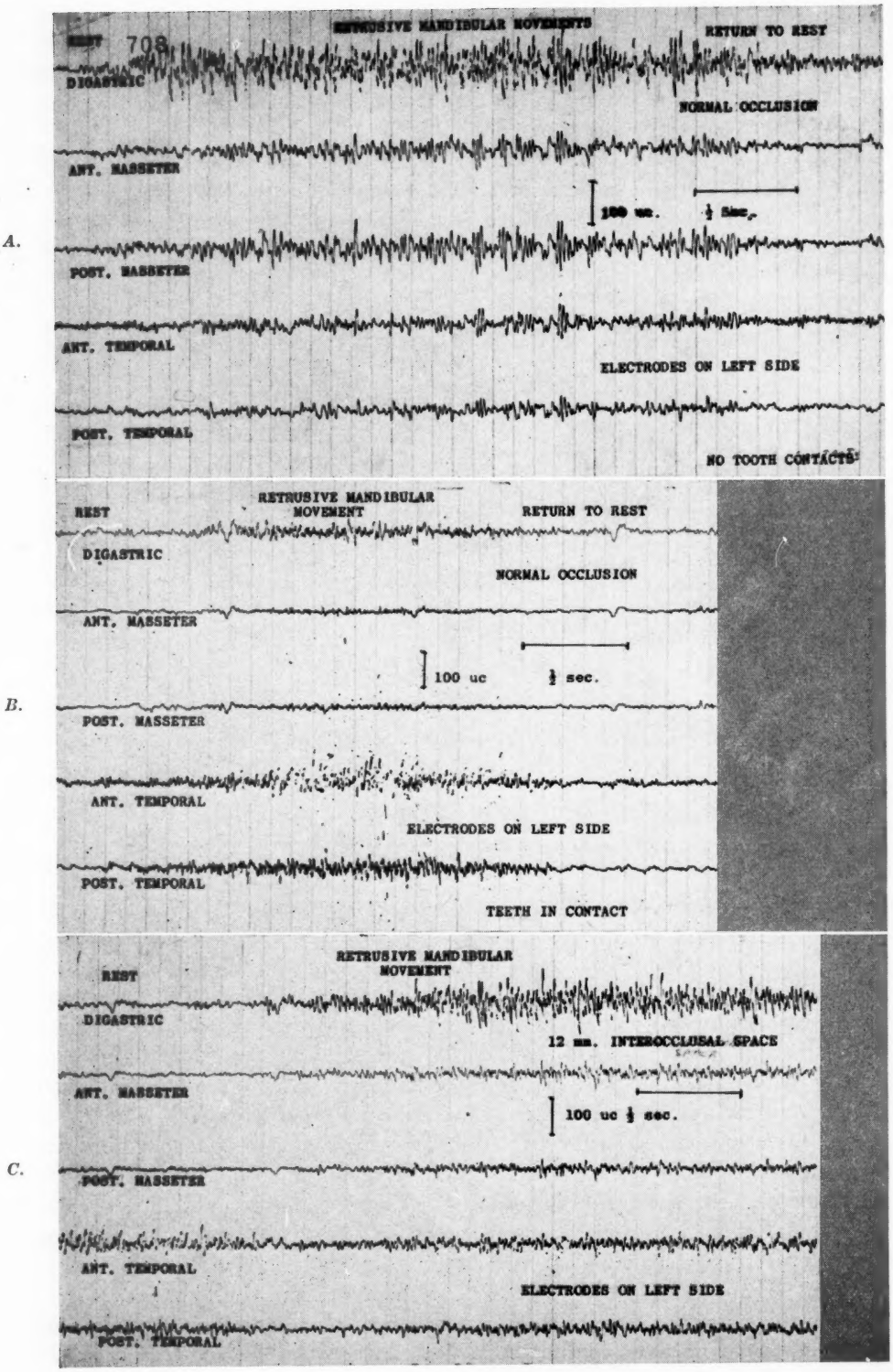


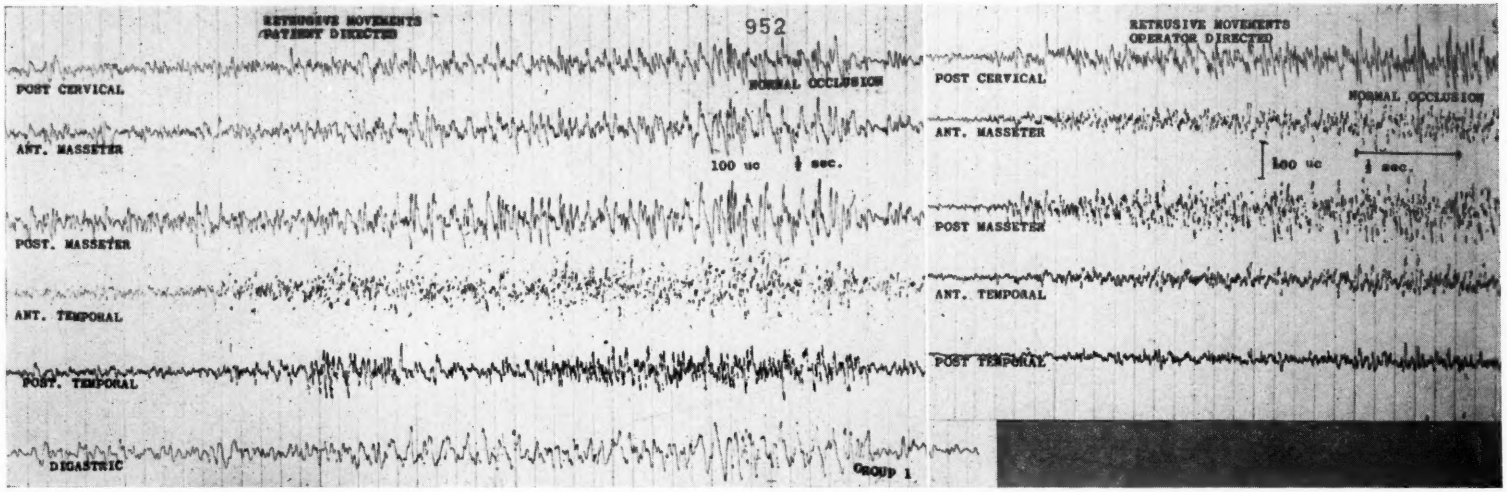
Fig. 10.—*A*, Retrusive mandibular movements. Normal occlusion with a 3 mm. interocclusal distance and no tooth contacts. *B*, Voluntary retrusive mandibular movements. Edentulous with a 12 mm. interocclusal distance. *C*, Voluntary retrusive mandibular movements. Edentulous with a 12 mm. interocclusal distance.

is called to the fact that, thus far, all movements originated from rest position, that is, the teeth were *not* in contact. In other words, no afferent impulses were forthcoming from the periodontal proprioceptors to help govern the musculature in its posterior guidance of the mandible. Therefore, instead of the mandible moving posteriorly, and slightly inferiorly, when the command was given to the patient to effect a mandibular retrusion, the movement which was recorded electromyographically had a strong inferior and an equally strong posterior component. Therefore, what we actually see in the tracings is a strong holding and fixing action of the temporomandibular joint by the masseter and temporal muscles, rather than a retrusive movement.

To illustrate further the significant role periodontal proprioception plays in guiding muscular activity in retrusive movements, we examine the electromyograms (Fig. 10,*B*) which illustrate the motor response from the temporal, masseter, and digastric muscles when the teeth were in very light contact during mandibular retrusion. While motor activity in the masseter and digastric muscles was smaller when compared with that shown in Fig. 10,*A*, there was a significant increase in action potentials from the temporal muscle. These data are more in keeping with the anatomic design of this muscle for retrusive movements than those when mandibular retrusion was not guided by periodontal proprioception.

Having pointed out the important role periodontal proprioception plays in directing retrusive mandibular movements, we are ready to consider muscular behavior of postural muscles of the mandible when sensory impulses from these valuable periodontal guides were erased by the loss of the natural teeth. The myogram (Fig. 10,*C*) illustrates the character of muscular behavior for a retrusive mandibular movement from a subject using a prosthesis having a 12 mm. interocclusal distance. In principle, this myographic response was nearly identical to the activity observed in the subject, with normal occlusion (Fig. 10,*A*), whose retrusive movements were not guided by proprioception from light tooth contacts. Thus, when afferent stimuli from periodontal proprioceptors were erased with the loss of the teeth, control of mandibular posture was again returned to the primitive neuromuscular control centers found in the temporomandibular joint capsules and in the sensory end-organs of the mandibular postural musculature. This is attested to by the fact that the character of the myograms, albeit not the amplitude, for all muscles from the edentulous subject were the same as those for the patient with normal occlusion whose retrusive movements were not guided by periodontal proprioception.

Therefore, it may be said that sensory impulses arising from periodontal proprioceptors are more discriminatory in their direction of mandibular posture than are those from capsule and muscle proprioceptors. These data lead us to suspect the ability of an edentulous subject to make a truly retrusive movement—a movement which would show the same sequence of electromyographic response as one guided by minimum tooth proprioception. From this evidence, it would seem logical to employ some form of external guidance, to direct the mandible posteriorly when centric relation is sought clinically. The form this guidance is to take is an open chapter needing clinical and research confirmation.



A. *B.*

Fig. 11.—*A*, Retrusive mandibular movements directed by the operator. *B*, Retrusive mandibular movements directed by the patient's hand.

To illustrate the fact we do not yet know what form this guidance shall take, we examine what takes place neuromuscularly when the mandible is retruded by the patient (Fig. 11,*A*) or by the operator (Fig. 11,*B*). In the first myogram, the patient forcibly directed the mandible back; the activity from the mandibular depressor and elevator muscles was quite violent. Motor activity of such magnitude indicates that the temporomandibular joint was being securely fixed by strained musculature to counteract this force. When such muscular activity is seen, agonist and antagonist muscles alike are attempting either to fix or to immobilize the bony members of a joint to prevent their dislocation. Then reciprocal innervation no longer obtains; it is replaced by cocontraction of agonist and antagonist muscles alike.

The motor response which took place when the mandible was directed posteriorly by the operator is illustrated in Fig. 11,*B*. Here the muscular behavior was the same, or very nearly so, as it was when the mandible's posterior directing force came from the patient.

From the electromyographic point of view, it would seem more physiologic, if it is an unstrained muscular status we are seeking, to obtain centric relation in some other manner than by retruding the mandible manually. Whether such a clinical discipline is possible is another question. The answer to this question can conceivably come from a combined clinician-physiologist research effort.

VERTICAL MANDIBULAR MOVEMENTS

Thus far, emphasis has been placed on electromyographic appraisal of muscular behavior for mandibular movements in the horizontal plane. Consideration will be given now to movements in the vertical plane. Here, as for movements in the horizontal plane, the starting and ending point was rest position.

The following discipline was adhered to: Electromyographic activity was recorded continuously for a very slow change in mandibular posture in the vertical plane. In the first phase of this movement, the mandible was depressed very gradually from rest position to a 15 mm. opening between the teeth. In the second phase, the mandible was very slowly elevated until occlusal contact was attained. In the last phase of the movement, the mandible returned to rest position.

The first electromyographic sequence was taken from a subject with normal occlusion. At rest, there was electromyographic silence (Fig. 12*A*). Coincident with the depression of the mandible, the digastric muscle entered a phase of contraction. As the downward path of the mandible continued from rest to a 15 mm. opening between the teeth, progressively more motor units contracted in the digastric muscle. As soon as the mandible started upward, motor unit activity in the digastric muscle ceased; the muscle became silent electromyographically. Motor activity in the temporal and masseter muscles did not follow the onset of silence in the digastric muscle as might be expected. Detectable activity was seen in these muscles only when light occlusal contact was made by the teeth. Electromyographic silence similar to that observed in the temporal and masseter muscles was seen by others in muscles of the extremities during very slow phasic movements (Gellhorn).[9] From this we may deduce that the electromyograph, sensitive as it is, is not sensitive enough to record motor activity from very slow marginal movements on either side of the rest position.

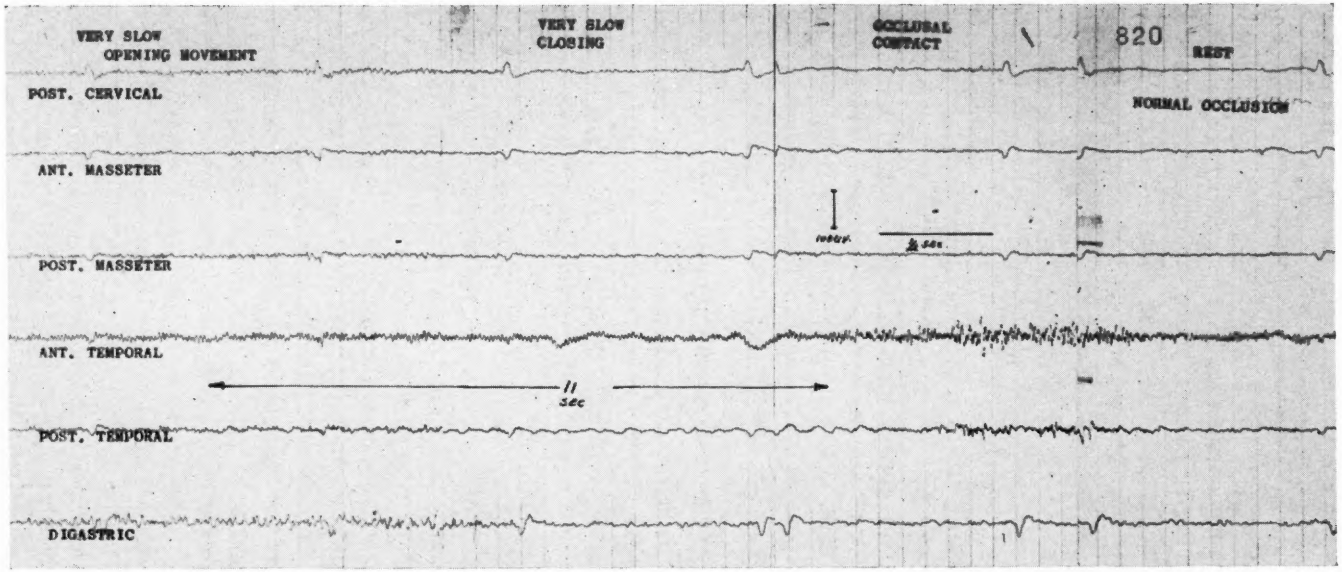


Fig. 12A.—Slow mandibular movements in a vertical plane. Natural teeth, 3 mm. interocclusal distance.

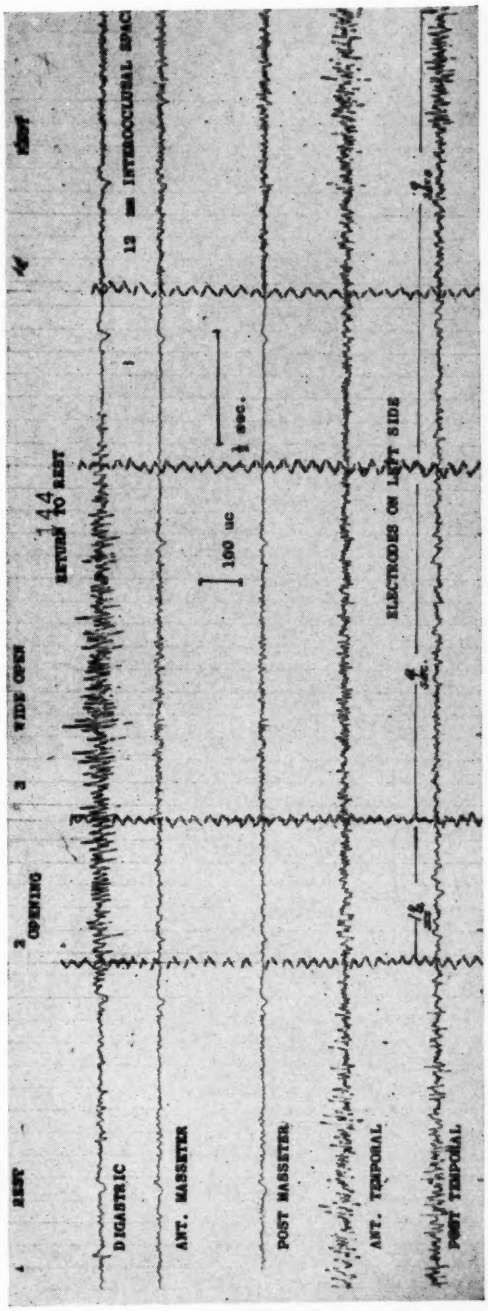


Fig. 12*B*.—Slow mandibular movements in a vertical plane illustrate a sustained spontaneous hyperactivity at rest. Edentulous with a 12 mm. interocclusal distance.

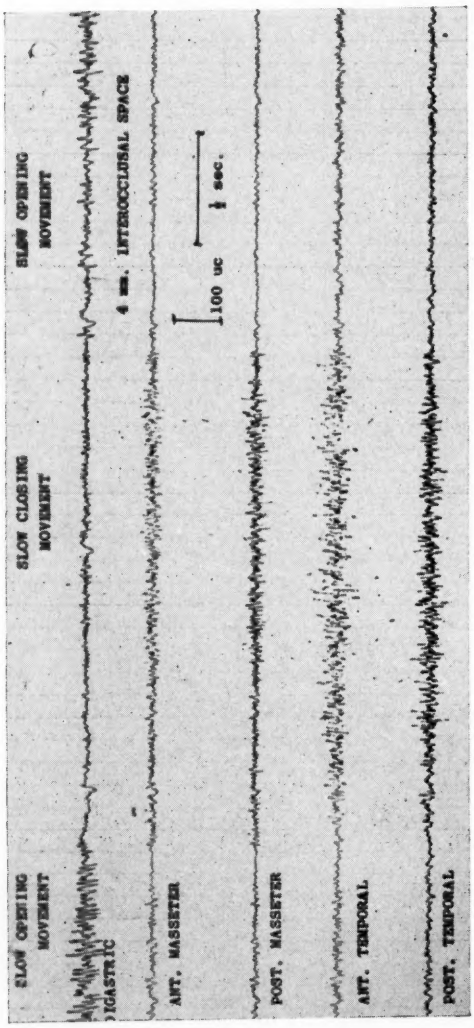


Fig. 12C.—Slow mandibular movements in a vertical plane. Edentulous with a 4 mm. interocclusal distance.

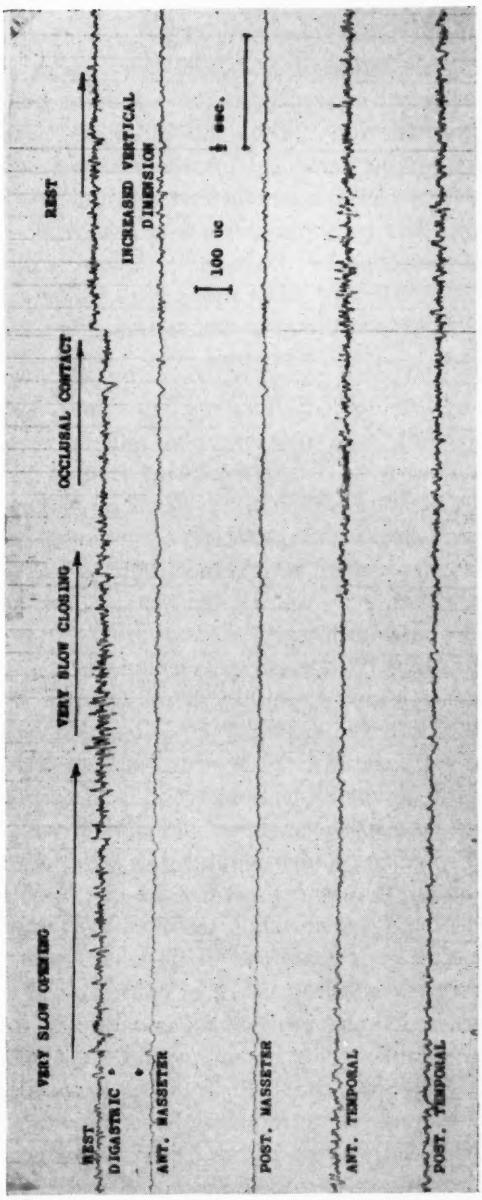


Fig. 12*D*.—Slow mandibular movements in a vertical plane. "High" dentures with the occlusal vertical dimension increased 6 mm. beyond rest.

VERTICAL MOVEMENTS THROUGH EXCESSIVE INTEROCCLUSAL DISTANCE

The electromyographic behavior of rest in the temporal and digastric muscles of subject with short dentures (12 mm. interocclusal distance) indicates that the anterior and posterior fibers of the temporal muscle, and to some degree the digastric muscle, were in a hypertonic state (Fig. 12*B*). This spontaneous hyperactivity in the temporal muscles stopped when the jaws began to open. During the entire phase of the downward movement of the mandible, the temporal muscle showed no spontaneous hyperactivity. When this movement was completed, and the mandible returned to rest, the temporal muscle returned to its former state of hyperactivity. From this, we may conclude that when willed movements were initiated, hyperactivity which had been present at rest ceased, only to return when voluntary movements were completed.

VERTICAL MOVEMENTS THROUGH AVERAGE INTEROCCLUSAL DISTANCE

When the upperward functional range of travel by the lower denture from rest position to occlusion was reduced from 12 mm. to 4 mm., spontaneous hyperactivity at rest was eliminated. Electromyographic silence very similar to that which was seen in the subject with normal occlusion ensued (Fig. 12*C*). This is significant because it points out two facts: (1) physical rest position of the mandible is not always synonymous with electromyographic silence in its muscles; and (2) the excessive distance through which mandibular muscles contract during the phasic movements, in chewing, in speech, and in swallowing, frequently influences the rest behavior of these muscles.

These findings make asking the following question necessary: Is it possible to record accurately and electromyographically a maxillomandibular relation by presence or absence of motor activity in mandibular postural muscles? Part of this question was answered when sustained spontaneous hyperactivity was discussed in resting muscle. Part of it will now be dealt with.

From observations on a significant number of patients with teeth in normal occlusion, and from a like number of edentulous subjects for whom dentures had been constructed within the limits of a 3 to 4 mm. interocclusal distance, electromyographic silence generally took place while the mandible was being gradually elevated to, or depressed from, rest position. This silence was noted while the mandible was in slow movement within a range of from 5 to 7 mm. interocclusal distance, and in rare instances, it was seen at as much as 9 mm. interocclusal clearance. This absence of recordable motor activity would continue during the upward movement of the mandible until the teeth would come into light occlusal contact. Upon light occlusal contact, the anterior and the middle group of temporal muscle fibers entered a contraction phase followed in a half second or less by the contraction phase of the posterior fibers. This motor activity represented the beginning stage of isometric contraction. More motor units entered into the contraction phase in the temporal muscles, and motor activity also began and continued to increase in the masseter muscles as the teeth were more firmly clenched in occlusion. When the command came from the brain to return the mandible to rest, motor activity ceased simultaneously in both muscles.

VERTICAL MOVEMENTS THROUGH LESS THAN NORMAL INTEROCCLUSAL DISTANCE

When the occlusal vertical dimension was opened with a "high" denture (beyond normal muscle length at rest), a condition obtained in which the mandibular elevator muscles were under light stretch. While in this state a low-level stretch activity was electromyographically observed from these muscles (Fig. 12*D*). When the opening movement of the jaws was begun, the digastric muscle responded in a manner previously described for similar movements. The temporal and masseter muscles showed only mild increase in electrical activity for the biggest part of the opening movement. As soon as this movement ceased and the upward movement of the mandible had begun, visible motor activity from muscles on either side of the mandible ceased. This electromyographic silence continued until the teeth came to occlusal contact. After the teeth had remained in occlusal contact for some time, the low-level stretch activity present before the mandible started to move down reappeared. This activity was similar, in magnitude, to that which was present in the masseter and temporal muscles before the mandibular movement was begun.

DISCUSSION

Early in this investigation, a chance observation revealed some significant information on the behavior of the temporal and digastric muscles in edentulous subjects. It was found that spontaneous hyperactivity would invariably appear in these muscles at rest, if the patients had worn dentures which functioned through an excessive interocclusal distance. Once this hyperactivity developed, it would continue even after the dentures were removed. Thus, it cannot be said that hyperactivity in these muscles was in any way related to stimulation by the dentures of touch and pressure sensory nerve endings found in the soft tissues overlying the bony residual ridges. To prevent hyperactivity in these muscles, the excessive interocclusal distance had to be reduced. When this was done with dentures which functioned through a 3 to 4 mm. interocclusal distance, this hyperactivity ceased.

The hyperactivity did not disappear spontaneously upon insertion of the correct dentures. In some instances, three or more meals had to be eaten before it disappeared; in others, it vanished after the patient chewed gum briefly. In only one instance did it remain after the correct vertical dimension was restored.

Spontaneous hyperactivity in the temporal muscles has been seen by Moyers[7] to exist in various conditions of malocclusion. It was observed also by Jarabak[8] in temporomandibular joint disturbances.

That spontaneous hyperactivity in rest position was likely due to functional overshortening of muscles is attested to by the fact that it disappeared when the vertical dimension was increased to the proper height. This spontaneous hyperactivity, occurring when the mandible was at physical rest was also abrogated by slow voluntary movements of the jaws in either horizontal or vertical planes. The fact that this hyperactivity was greatest at rest, and diminished or completely disappeared when voluntary movements were induced, led us to believe we were dealing with a tremor or an unsteady muscle response, a phenomenon which is seen frequently in edentulous patients when their jaws are at rest.

To explain the etiology for these tremors, several things must be considered. First, it must be realized that muscle works most efficiently when it is called upon to contract within perimeters of its normal physiologic length. If these perimeters of muscle length are changed, the tension recorded in muscle and tendon proprioceptors is altered. These alterations in tension, brought about by excessive muscle shortening, are then imposed on the neurocontrol system, which by reflex sets up the pattern of spontaneous hyperactivity or a tremor to compensate for this loss in tension.

Does this spontaneous hyperactivity seen in vertical overclosures preclude the establishment of physiologic rest position? There are two answers for this question. If one is contented to use a static cephalometric roentgen record and to measure distances between points of reference on a bony profile, the answer is no, because these small movements induced by muscle tremor cannot be shown roentgenographically. On the other hand, if rest position is to be appraised by electromyographically recorded silence from agonist and antagonist muscles responsible for mandibular posture, the answer is yes. A true physiologic position cannot exist when mandibular postural muscles are in tremor.

This leads us to ask: how can this hyperactivity be removed so that correct vertical dimension can be established? In Fig. 12*B*, it was demonstrated that spontaneous hyperactivity was erased during very slow mandibular movements in either the horizontal or the vertical planes. During these movements, muscles were stretched. For this reason, exercises suggested by Boos[9] were tried on several edentulous subjects for a half hour prior to registering rest position. Hyperactivity disappeared for sufficiently long enough periods to allow a reasonably accurate registration of rest position. This procedure offers clinical promise, and it needs further exploration. In addition to the Boos method, spontaneous hyperactivity (tremor) can also be minimized by any one of a number of muscle relaxant drugs.

These studies illustrate the wide versatility of the electromyograph in muscle physiology. It would seem that it ought to lend itself ideally to clinical studies on rest position and to establishing a correct vertical dimension between the two jaws. Unfortunately, this is only partially true. This was shown by our inability to record action potentials for small slow marginal movements in the vertical plane, on either side of rest position (Fig. 12*A, B,* and *D,* and to some degree in *C*). Since slowly performed mandibular movements from 1 to 3 mm. on either side of rest position are difficult to identify by changes in action potentials, the use of the electromyograph for establishing this maxillomandibular relation has clinical limitations. However, these limitations do not preclude its use in physiologic studies on the behavior of agonist and antagonist muscles attached to the mandible and responsible for its movements in mastication, in speech, and in rest position. From these studies may come information which ultimately may be translated into a precise physiologic method for establishing a correct maxillomandibular relation at rest.

What is the clinical significance of this work on muscular behavior on either side of rest position? To answer this, we need only to realize the role a prosthodontist plays in the maintenance of the chewing apparatus.

CLINICAL SIGNIFICANCE

The prosthodontist, like the limb-designing surgeon who supplies prosthetic appliances to replace lost appendages, designs prostheses to replace lost teeth. To design these appliances correctly, he must understand muscle dynamics which act on the temporomandibular joint, just as limb surgeons have to understand muscle dynamics of the joints for which they supply a kineplastic arm or leg. The muscles of mastication act on the temporomandibular joint in essentially the same manner as do the muscles of the extremities on their respective joints. The laws which govern movements and posture of the arm or the leg also govern movement and mandibular posture. For a clearer understanding of these laws, two inescapable facts which were given to us by physiologists many years ago ought to be borne in mind. First, muscle has a limited useful excursion which is proportional to its over-all length. Thus it follows that a shorter muscle will contract through a lesser distance more effectively than through a longer one. Second, tension developed in the muscle during contraction is not constant throughout the range of excursion but varies at different lengths. The tension becomes less as a muscle shortens and greater as it lengthens. Ideal tension is developed at physiologic resting length.

Muscle tension is a property of muscle to which the prosthodontist inadvertently gives clinical consideration while he tries to establish, accurately, a correct maxillomandibular relation. Muscle tension has two components, one active and one passive. Active tension is the property of muscle tissue, that is, of the myofibrils. Passive tension is a property of connective tissue which surrounds the muscle fibers and which extends peripherally to form the tendonous attachments which fasten muscles to their respective bony levers. Thus, a muscle rich in connective tissue, like the masseter, will have a much higher total-tension curve than a muscle with less connective tissue, such as the temporal.

If a denture is made which will increase the vertical dimension of occlusion beyond the resting length of the muscles attached to the mandible, these stretched muscles will develop a greater than normal tension. Conversely, if a denture is made which permits the muscles to shorten beyond their physiologic length, tension is lost. A shortened muscle atrophies; its muscle tissue is replaced by connective tissue.

This property of muscle and of its connective tissue is clinically significant to the prosthodontist. If he can correctly establish maxillomandibular relation and accurately calculate the needed interocclusal distance between the denture teeth, he can maintain muscle within its physiologic length and obtain maximum efficiency from it.

If he miscalculates and increases the vertical dimension of occlusion, tension is increased in the muscle. This tension is in turn transferred in terms of greater occlusal impact to the residual ridges. If he miscalculates in the other direction, that is, if he reduces the vertical dimension of occlusion, tension is decreased, causing the muscles to atrophy and to lose some of their efficiency. What reduced muscle tension means to the underlying residual ridges needs considerable research.

SUMMARY

Mandibular movements on either side of the rest position were electromyographically evaluated in subjects wearing dentures. It was found that a correct vertical dimension of occlusion coupled with an adequate interocclusal distance between the teeth of the upper and lower dentures is essential to maintain the muscles of mastication at their most efficient functional length. When vertical overclosure obtained, there was loss of muscle tension which frequently caused spontaneous hyperactivity. When the vertical dimension was excessive, muscle tension increased. An interocclusal space, to be adequate, must be sufficient to permit muscles to function within their physiologic length. For edentulous patients this was found to be in the neighborhood of 4 mm.

REFERENCES

1. Fick, A.: Mech. Arbeit und Wärmeentwick l bei der Muskeltätigkeit, Leipzig, 1882.
2. Fenn, W. O.: (Cited by Höber, R.): Physical Chemistry of Cells and Tissues, Philadelphia, 1945, Blakiston, pp. 447-522.
3. Hunter, J.: The Natural History of the Human Teeth, ed. 1, London, 1771, John Johnson.
4. Thompson, J. R.: The Rest Position of the Mandible and Its Significance to Dental Science, J.A.D.A. **33**:151-180, 1946.
5. Sherrington, Sir Charles: Integrative Action of the Nervous System, New Haven, 1920, Yale University Press.
6. Gellhorn, E.: Physiological Foundations of Neurology and Psychiatry, Minneapolis, 1953, Universiy of Minnesota Press.
7. Moyers, R. E.: Temporomandibular Muscle Contraction Patterns in Angle Class II, Division I Malocclusions: An Electromyographic Analysis, Am. J. Orthodontics **35**: 837, 1949.
8. Jarabak, J. R.: An Electromyographic Analysis of Muscular and Temporomandibular Joint Disturbances Due to Imbalances in Occlusion, Angle Orthodont. **26**:170-190, 1956.
9. Boos, Ralph H.: Physiologic Denture Technique, J. Pros. Den. **6**:716, 1956.

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Readers' Round Table

Prince Edward Island, Canada

Editor, The Journal of Prosthetic Dentistry:

I was interested in an article in the May, 1957, issue of the Journal by Dr. Anthony K. Kaires ["Palatal Pressures of the Tongue in Phonetics and Deglutition," J. Pros. Den. 7:305-317, 1957] in which he describes some experiments conducted with electronic strain gauges. It occurred to me that the theory of Dr. T. E. J. Shanahan and others, including myself, could be submitted to proof by the use of this method of investigation. We believe that the swallowing reflex gives an accurate guide for measuring the vertical dimension of a face, and thus we arrive at the correct height of the plane of occlusion in the mouth. However, since it is possible to register different amounts of opening in swallowing, it could be that there does not exist a constant reflex action always at the same level. It would be useful to have sufficient experimental evidence to prove or disprove the theory. I believe it would be found to be a fact but cannot be sure at this stage. Perhaps some reader could have such an experiment conducted.

Sincerely,

James D. Reddin, D.D.S.

Book Reviews

ORAL HISTOLOGY AND EMBRYOLOGY. Edited by Balint J. Orban, M.D., D.D.S. Fourth edition. 379 pages, illustrated, indexed. St. Louis, 1957. The C. V. Mosby Company. Price $9.00.

The fourth edition of this now "classic" textbook follows the format of former editions. Incorporated in it are not only minor technical changes and corrections, but also the latest concepts of tissue structure as divulged by recent electron microscope and histochemical studies. New photographs have been added to the already splendid collection of illustrations.

An attempt has been made to clarify the description of the early development of the human face. This has been successful in part. The entire first chapter could be rewritten for greater clarification of this complicated and elusive subject. Further simplification could be done without detracting from its value or omitting salient facts.

Although the editor states in the preface that ". . . it is not the purpose of this text to force any of the ideas herein expressed . . ." upon the reader, one cannot but note the dogmatic presentation of the material concerning the epithelial attachment. But, as the editor further points out, ". . . each teacher will . . . add to the text, subtract from it, or change the concepts."

The book in general is well written and beautifully and profusely illustrated. Each chapter is concluded with adequate references. For the most part the material presented has been well placed at the student level of comprehension. Although intended primarily as a textbook for dental students, it will prove very useful to the interested dental practitioner.

Rollin E. Mallernee

APPLIED DENTAL MATERIALS. By John N. Anderson, B.D.S. (Sheffield). 422 pages, 31 illustrations, indexed. Oxford, 1956, Blackwell Scientific Publications. Springfield, Ill., 1956, Charles C Thomas. Price $7.50.

This book is intended to serve both as a textbook for students and also as a reference book for dental practitioners and their technicians. The author states that the book is intended as a guide for everyday manipulation of dental materials rather than as a scientific treatise upon their properties.

The subject matter is up to date and well presented in an easily understood manner. The organization of the material is good. The book would be greatly improved by the addition of more illustrations. Almost all of the illustrations are line drawings, with only three photographic reproductions.

The printing is good, but the paper and binding are inferior to those of the average American dental textbook.

The book is divided into five sections which arrange the material as follows: A, general physical properties of dental materials and the application of these properties to dentistry; B, cast and wrought metals; C, dental precision casting; D, general nonmetallic dental materials; E, filling materials.

A short chapter on the technical procedures involved in the making of castings with the chrome cobalt alloys is included in Section B.

The author has effectively accomplished his stated purpose in writing the book. It should be acceptable as a textbook or as supplemental reading for dental students. However, its value as a textbook would be increased with the addition of more illustrations. It should also be a valuable addition to the library of the serious dental practitioner or technician.

William C. Dew

PARTIAL DENTURES. By Merrill G. Swenson, D.D.S., F.I.C.D., F.A.D.P., and Louis G. Terkla, D.M.D. 421 pages, illustrated, indexed. St. Louis, 1955, The C. V. Mosby Company. Price $12.00.

This book was written to present an organized teaching plan for the construction of partial dentures together with the principles and fundamentals necessary for such dental procedures. It is designed to be used as a textbook for the dental student and as a source of information for the practicing dentist.

The contents of the book are logically presented, and the organization is such as to result in a minimum of confusion to the reader. It is written in a manner easily read and understood. The 423 illustrations leave nothing to be desired. The paper, printing, and binding used in the book are of the best quality.

The book is divided into two parts, each part making up approximately one-half the total content. Part I is a step-by-step procedure for the construction of a partial denture using a one-piece casting. There are no deviations here to explain fundamentals and principles. Complete diagnosis, study materials, preparation of abutment teeth, impressions, mountings, surveying, duplicating, waxing of frameworks, casting, tooth setting, flasking, processing, insertion, and equilibration are each discussed in detail and thoroughly illustrated in this section.

Part II deals with the fundamentals and related factors of the procedures described in Part I. The theories of surveying, design, tooth preparation, clasping and clasp form, and correction of premature contacts in centric relation of natural teeth are stressed. Some fifty different designs, covering almost any conceivable clasping situation for the various classes of partial dentures, are illustrated and completely described. The book is indexed, and a glossary of terms used in partial denture prosthodontics is included.

It is the opinion of the reviewer that this book would serve very adequately as a text for dental students. Any dentist with any interest in partial denture prosthodontics will find it of value.

Judson C. Hickey

PROSTHETIC DENTISTRY. A Clinical Outline. By F. Winston Craddock, B.A., Dip. Ed., M.S.D., D.D.S. Third edition, 430 pages, illustrated, indexed. London, 1956, Henry Kimpton. Price $6.00.

The author has done well in his attempt to cover the general field of prosthetic dentistry in a style which makes for easy reading and understanding of the topics discussed. Illustrations are well chosen and add clarity to the didactic content. All of the most important phases of prosthodontics are covered in the 14 chapters without the loss of interest which sometimes accompanies more detailed descriptions of technical phases and theories dealing with these topics.

The first two chapters logically cover the anatomy and examination of the mouth. Chapters 3 and 4 include impression-making and pouring of casts. Chapter 5 deals with centric occlusion, and Chapter 6 is a discussion of various types of articulators. This type of chronological order, first theory and then procedure, is continued through Chapter 14. I feel that this arrangement aids in maintaining the reader's interest at a high level and would make this book of particular value to students who might use it for a text. Chapters 8 through 14 include: Processing, Principles of Retention, Insertion of Full Dentures, Partial Dentures (very well illustrated), Aesthetics and Immediate Dentures, Splints and Radium Applicators and Obturators, and Surgical Preparation of the Mouth. Included is an excellent and complete bibliography for each chapter.

The general subject matter is effectively presented, including a good review of the major prosthodontic problems to be encountered, techniques, methods, and procedures for handling these difficulties, and the anticipated prognosis. Unfortunately, the author's conclusions following excellent descriptive matter would leave considerable doubt in the mind of the student as to the importance or value of certain fundamental principles and technical procedures involved in the fabrication of prosthodontic appliances. For example, the use of a face-bow and the choice of an anatomic articulator are mentioned as good procedures but are not considered as essential, due to the adaptability of the patients and the oral tissues involved.

To the experienced prosthodontist, the book presents an interesting discussion of the author's views; although certain procedures seem somewhat outdated considering new advances in techniques and dental materials available. The chapter on partial dentures would leave much room for argument on leverage distribution, and the lack of emphasis on the important place removable partial denture prosthodontics occupies today. *Prosthetic Dentistry* would be a valuable adjunct to those teaching prosthodontics, either as a text or in preparing lecture material, and the few shortcomings mentioned are heavily outweighed by excellent descriptive material included.

Julian B. Woelfel

THE OFFICE ASSISTANT IN MEDICAL OR DENTAL PRACTICE. By Portia M. Frederick and Carol Towner. 351 pages, illustrated, indexed. Philadelphia, 1956, W. B. Saunders Company. Price $4.75.

Portia M. Frederick, Instructor in Medical Office Assisting at Long Beach City College, and Carol Towner, Executive Assistant in the Department of Public Relations of the American Medical Association, have coauthored a book designed primarily to serve as text material in formal training programs for office assistants in medical and dental practices. However, the book can be an excellent reference and guide to women who have not had the opportunity for such training but who are engaged in these fields of work and to those who are contemplating these careers.

The authors have employed a simple, readable style of writing to present a well-organized coverage of the general duties of the assistant without going into detailed technical phases of the work. In 26 chapters, they discuss various aspects of the career of office assisting, including ethics, reception of patients, telephone technique, appointments, correspondence, patient records, business procedures, sterilization, care of instruments, examinations, insurance programs, therapy, supplies, professional organizations, library and editorial duties. In an appendix they have suggested additional references and provided a list of common abbreviations and symbols.

The illustrations are reproductions of various charts and forms frequently used in medical and dental offices and line drawings of a few technical procedures. The chapter organization is good, and the topic divisions are useful for ready reference. The quality of binding, paper, and printing is adequate.

The reviewer recommends this book to all readers who are concerned with the problems of office asissting. It is suggested that when this book is revised, the authors change the wording "doctors and dentists," to "physicians and dentists."

Marice K. Musgrove.

News and Notes

MEETINGS

American Denture Society, Americana Hotel, Miami Beach, Fla., Nov. 1 to 3, 1957.

The first national meeting on the subject of *Ultrasonic Dentistry* will be held at the Hotel Seville, in Miami Beach, Fla. on Nov. 3, 1957. The Symposium will be under the auspices of "The Committee for the Study of Ultrasonics in Dentistry." The topics to be discussed include: "Suggested Techniques and Instrumentation in the Use of Ultrasonics for Preparing Teeth for Crowns and Bridge Retainers" by Stanley D. Tylman; "Ultrasonic Cavity Preparation" by Harry H. Postle; "Ultrasonic Amalgam Condensation" by Eugene W. Skinner; "The Applications of the Ultrasonic Dental Unit to Periodontics" by John R. Wilson; "The Biologic Aspects of the Use of the Ultrasonic Instrument" by Helmut Zander, Leo Zack, and Rollin E. Mallernee.

For further information, write to Dr. Stanley D. Tylman, College of Dentistry, University of Illinois, Room 666, 808 South Wood Street, Chicago, Ill.

The Greater New York Dental Meeting, Hotel Statler, New York City, Dec. 9 to 13, 1957.

American Denture Society, Congress Hotel, Chicago, Ill., Jan. 31 and Feb. 1, 1958.

American Academy of Crown and Bridge Prosthodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 1 and 2, 1958.

American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 1 and 2, 1958.

American Association for Cleft Palate Rehabilitation, St. Francis Hotel, San Francisco, Calif., April 24 to 26, 1958.

This Association is composed of medical, dental, and paramedical specialists who are interested in the rehabilitation of persons with cleft lips and palates.

ANNOUNCEMENTS

The State University of Iowa, College of Dentistry, announces a Conference on Prosthetic Dentistry to be held Sept. 25 to 27, 1957. For further information, write to Dr. William D. Coder, Extension Division, State University of Iowa, Iowa City, Iowa.

The University of Illinois, College of Dentistry, Department of Crowns and Fixed Partial Dentures, announces a two-year training program leading to the Master of Science degree.

For further information, write to Dr. Stanley D. Tylman, Head of the Department of Crowns and Fixed Partial Dentures, University of Illinois, College of Dentistry, 808 South Wood Street, Chicago 12, Illinois.

New York University, College of Dentistry announces a forty-hour postgraduate course in the Principles and Practice of Endodontics beginning Wednesday, Oct. 23, 1957, and continuing for five weeks.

For further information, write to Director, Postgraduate Division, New York University, College of Dentistry, 209 East 23rd Street, New York 10, N. Y.

Tufts University School of Dental Medicine announces the following postgraduate refresher courses

Crown and Bridge Prosthesis for the General Practitioner, Dr. Frank A. Eich, Oct. 21, 28; Nov. 4, 18, 25; Dec. 2, 1957.

Clinical Endodontics, Dr. Arthur H. Pearson, Nov. 8, 15, 22; Dec. 6, 13, 20, 1957.

Periodontics, Dr. Balint Orban, Feb. 26, 27, 28, 1958.

Crown and Bridge Prosthesis Participation Course, Dr. R. Sheldon Stein, Feb. 28; March 1, 7, 8, 14, 15, 22, 29, 1958.

For further information, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

The Beth Israel Hospital, Dental Department, announces the following postgraduate course: A two-week seminar in Periodontia, Oct. 7 to 18, 1957, to be given by Dr. Henry M. Goldman and staff.

For further information, write to Director of Public Relations and Education, Beth Israel Hospital, 330 Brookline Ave., Boston 15, Mass.

The University of Alabama, School of Dentistry announces the following refresher courses:

The Use of Drugs in Dental Practice, Sept. 21-23, 1957.

Practical Root Canal Therapy, Sept. 27-29, 1957.

Partial Denture Prosthesis, Oct. 5-7, 1957.

Office Management and Psychology of Dentist-Patient Relationship, Oct. 10, 1957.

Insurance, Investments, and Estate Planning, Oct. 12, 13, 1957.

Oral Pathology-Oral Medicine, Oct. 14-18, 1957.

Dental Materials: Practical Application and Evaluation of Newer Advances and Changing Concepts, Oct. 19, 20, 1957.

Effective Speaking for Professional People, Oct. 26-29, 1957.

Oral Rehabilitation, Nov. 9, 10, 1957.

The Theory and Practice of Periodontics, Nov. 16-18, 1957.

Histopathology of the Periodontium, Nov. 19-23, 1957.

Dental Assisting, Nov. 23, 24, 1957.

Emergency Care in Dental Practice, Nov. 30-Dec. 2, 1957.

Laboratory Techniques, Dec. 7, 8, 1957.

Practical X-ray Technique and Interpretation, Dec. 9-13, 1957.

High Speed Techniques in Operative Dentistry, Jan. 3-5, 1958.

Treatment Planning and Case Presentation, Jan. 11-13, 1958.

Immediate Root Canal Therapy Followed by Apicoectomy, Jan. 16, 17, 1958.

The Management of Pain in Dental Practice, Jan. 25, 26, 1958.

Nutrition and Dentistry, Feb. 1-3, 1958.

Effective Speaking for Professional People, Feb. 4, 6, 11, 13, 18, 20, 25, 27, 1958.

English for Professional People, Feb. 5, 12, 19, 26, March 5, 12, 19, 26, April 2, 9, 16, 23, 30, and May 7, 14, 21, 28, 1958.

Periodontology for the General Practitioner, Feb. 8-10, 1958.

Preventive Orthodontics, Feb. 15-17, 1958.

Laboratory Procedures in Crown and Bridge Prosthesis for the General Practitioner, Feb. 22-24, 1958.

Occlusal Adjustment: Its Relation to Dental, Periodontal, and Temporomandibular Joint Problems, March 1-3, 1958.

Insurance, Investments, and Estate Planning, March 4, 5, 1958.

Income Tax Guidance, March 6, 1958.

Applied Maxillofacial Anatomy, March 8-10, 1958.

Practical Exodontia, March 29-31, 1958.

Root Canal Therapy, April 12-14, 1958.

Pedodontics for the General Practitioner, April 19-21, 1958.

Complete Denture Prosthesis, May 4-6, 1958.

Management of Infections in Dental Disease, May 10-12, 1958.

Surgical Anatomy of the Head and Neck, May 17-19, 1958.

Etiology and Diagnosis of Pain of Dental Origin, May 20, 21, 1958.

Removable Orthodontic Appliance Construction, May 24-26, 1958.

For further information and application, write to Dr. Arthur H. Wuehrmann, University of Alabama School of Dentistry, Medical Center, Birmingham 3, Alabama.

Emory University, School of Dentistry announces the following postgraduate courses:

Improved Techniques in Periodontia, Dr. Frank E. Beube, Oct. 28, 29, 1957.

Minor Tooth Movement, Dr. Frank F. Lamons and Dr. Charles H. Smith and staff, Dec. 4 to 6, 1957.

Occlusion, Dr. Sigurd Ramfjord, Feb. 3 to 7, 1958.

Posterior Crown and Bridge Prosthodontics, Dr. George H. Moulton and Staff, March 5 to 7, 1958.

Pedodontics, Dr. Ralph L. Ireland and Staff, April 23 to 25, 1958.

Refresher Course in Immediate Denture Prosthesis, Dr. L. B. Brown, Dr. H. J. Harpole, Dr. J. C. Garland, and Dr. Parker E. Mahan, May 8, 1958.

Periodontia (Participation Course), May 19 to 23, 1958.

For further information, write to Emory University, School of Dentistry, 106 Forrest Ave., N.E., Atlanta 3, Ga.

Temple University School of Dentistry announces the following postgraduate courses:

Clinical Endodontics, Dr. Leonard Parris and Dr. Herbert Schilder, Oct. 14 to 19, 1957.

Oral Roentgenology, Dr. Gordon Fitzgerald, Oct. 24, 25, and 26, 1957.

Complete Denture Construction, Dr. Bernard Jankelson, Jan. 6 to 10, 1958.

Rehabilitation of the Edentulous Patient, Dr. Bernard Jankelson, Jan. 13 to 18, 1958.

Advanced Orthodontics, Dr. Robert H. W. Strang, Jan. 19 to Feb. 1, 1958.

Periodontal Prosthesis, Dr. Morton Amsterdam and Dr. Walter Cohen, Feb. 10 to 14, 1958.

Practice Administration, Dr. Jay H. Eshleman, Feb. 15, 1958.

Practical Uses of Electrosurgery in Dentistry, Dr. Maurice Oringer and Dr. Martin Entine, March 1, 1958.

Oral Medicine, Dr. Leonard Rosenthal and Dr. Lester Burket, March 3 to 7, 1958.

Advanced Surgical Techniques in Periodontal Therapy, Dr. Saul Schluger, April 21 to 25, 1958.

The Washed Field Technique in Accelerated Dentistry, Dr. E. O. Thompson, May 5 and 6, 1958.

Endodontics—Immediate Root Resection, Dr. Louis Grossman and Dr. Leonard Parris, June 3 to 7, 1958.

The Porcelain Jacket Crown, Dr. Joseph Ewing, June 11, 12, 18, 19, and 25, 1958.

For further information and application, write to Dr. Louis Herman, Postgraduate Division, Temple University School of Dentistry, 3223 North Broad Street, Philadelphia 40, Pa.

The Ohio State University, College of Dentistry announces the following postgraduate courses:

Oral Surgery, Dr. Morgan L. Allison, Oct. 14, to 18, 1957.

General Anesthesia, Dr. Morgan L. Allison, Oct. 21 to 25, 1957.

Complete Denture Prosthodontics, Dr. Carl O. Boucher, Nov. 18 to 22, 1957, and Feb. 17 to 21, 1958.

Endodontics, Dr. J. Henry Kaiser, Jan. 13 to 17, 1958.

Review of Dental Hygiene (For Hygienists), Staff, Jan. 27 to 29, 1958.

Crown and Bridge, Dr. Thomas F. McBride, Feb. 10 to 14, 1958.

Partial Denture Prosthodontics, Dr. Victor L. Steffel, Feb. 24 to 28, 1958.

Pedodontics, Dr. Lyle S. Pettit and Dr. Benjamin H. Williams, March 3 to 7, 1958.

Oral Pathology, Dr. Hamilton B. G. Robinson, March 10 to 14, 1958.

General Anesthesia, Dr. Morgan L. Allison, April 28 to May 2, 1958.

Periodontics, Dr. John R. Wilson, May 5 to 9, 1958.

Review of Clinical Dentistry, Staff, May 12 to 16, 1958.

Pharmacology, Dr. William R. Kampfer, May 19 to 23, 1958.

For further information and application, write to Postgraduate Division, The Ohio State University, College of Dentistry, Columbus 10, Ohio.